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ON TECHNOLOGY PROBLEMS FOR

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Christopher Freeman

The Economics of Industrial Innovation

Penguin Books

Even though the survival and profitability constraints are obviously of the greatest importance in explaining firm behaviour, we conclude from chapter 7 that rational profit-maximizing behaviour (or wealth maximizing) is seldom possible in the face of the uncertainties associated with *individual* innovation projects. This is not to deny that neo-Classical short-run theory is a valuable, precise, abstract model of firm behaviour, but it means that this model has limited relevance, and that other ways of interpreting and understanding innovative behaviour are needed. One possible approach to such a theory (and it is no more than a first approach) is to look at the various *strategies* open to a firm when confronted with technical change. Such an approach does not look to an equilibrium which is never attained, but does take into account the historical context of any industry in a particular country. This chapter classifies some possible strategies, and discusses them in relation to R and D, and other innovative activities of the firm.

Any classification of strategies by 'types' is necessarily somewhat arbitrary and does violence to the infinite variety of circumstances in the real world. The use of such ideal 'types' may nevertheless be useful for purposes of conceptualization, just as the use of the concepts of 'extrovert' and 'introvert' is useful in psychology. In practice there is an infinite gradation between types, and many individuals possess characteristics of both types. Moreover, individuals (and firms) do not always behave 'true to type'. Finally, people and firm strategies are always changing, so that generalizations which were true of a previous decade will not necessarily be true of the next.

Any firm operates within a spectrum of technological and market possibilities arising from the growth of world science and the world market. These developments are largely independent of the individual firm and would mostly continue even if it ceased to exist. To survive and develop it must take into account these limitations and historical circumstances. To this extent its innovative activity is not free or arbitrary, but historically circumscribed. Its survival and growth depend upon its capacity to adapt to this rapidly changing external environment and to change it. Whereas traditional economic theory largely ignores the complication of world science and technology and looks to the market as *the* environment, changing technology is a critically important aspect of the environment for firms in most industries in most countries.

Within these limits, the firm has a range of options and alternative strategies. It can use its resources and scientific and technical skills in a variety of different combinations. It can give greater or lesser weight to short-term or long-term considerations. It can form alliances of various kinds. It can license innovations made elsewhere. It can attempt market and technological forecasting. It can attempt to develop a variety of new products and processes on its own. It can modify world science and technology to a small extent, but it cannot predict accurately the outcome of its own innovative efforts or those of its competitors, so that the hazards and risks which it faces if it attempts any major change in world technology are very great.

Yet not to innovate is to die. Some firms actually do elect to die.[1] A firm which fails to introduce new products or processes

1. Metcalfe's study (1970) on Lancashire cotton firms showed that a large number were not willing to purchase a simple new piece of equipment (a size box), even though it cost less than £100, and the pay-back period was clearly demonstrated by the Research Association and the manufacturers to be less than one year. Mansfield's study (1971) of the adoption process of numerically-controlled machine tools in the American tool-and-die industry similarly showed that many firms did not intend to adopt, 'even when firm owners granted that the lack of numerical control would soon be a major competitive disadvantage'. Mansfield estimated the median pay-back period in this case as five

in the chemical, instruments or electronics industries cannot survive, because its competitors will pre-empt the market with product innovations, or manufacture standard products more cheaply with new processes. Consequently, if they wish to survive despite all their uncertainties about innovation, most firms are on an innovative treadmill. They may not wish to be 'offensive' innovators, but they can often scarcely avoid being 'defensive' or 'imitative' innovators. Changes in technology and in the market and the advances of their competitors compel them to try and keep pace in one way or another. There are various alternative strategies which they may follow, depending upon their resources, their history, their management attitudes, and their luck (Table 37).

They differ from those which are normally considered in relation to the economist's model of perfect competition, since two of the assumptions of this model are perfect information and equal technology. Both of these assumptions are completely unrealistic in relation to most of the strategies we are considering, but they are perhaps relevant for the 'traditional' strategy which may be followed by firms producing a standard homogeneous commodity under competitive conditions. Such firms can concentrate all their ingenuity on low-cost efficient production and can ignore other scientific and technical activities or treat them as exogenous to the firm. Some products are still produced under conditions which may sometimes approximate to traditional competitive assumptions but they are only at one end of a spectrum. The 'traditional' strategy is essentially non-innovative, or insofar as it is innovative it is restricted to the adoption of process innovations, generated elsewhere but available equally to all firms in the industry. Agriculture, building and catering are examples of industries which in some respects approximate to these assumptions.

We consider six alternative strategies, but they should be considered as a spectrum of possibilities, not as clearly definable pure forms. Although some firms recognizably follow

years and suggests that in many firms in this category the owners were close to retirement.

Table 37 Strategies of the firm

Strategy	*In-house scientific and technical functions within the firm*									
	Fundamental research	*Applied research*	*Experimental development*	*Design engineering*	*Production engineering – Quality control*	*Technical services*	*Patents*	*Scientific and technical information*	*Education and training*	*Long-range forecasting and product planning*
offensive	4	5	5	5	4	5	5	4	5	5
defensive	2	3	5	5	4	3	4	5	4	4
imitative	1	2	3	4	5	2	2	5	3	3
dependent	1	1	2	3	5	1	1	3	3	2
traditional	1	1	1	1	5	1	1	1	1	1
opportunist	1	1	1	1	1	1	1	5	1	5

Range 1–5 indicates weak (or nonexistent) to very strong

one or other of these strategies, they may change from one strategy to another, and they may follow different strategies in different sectors of their business.

'Offensive' strategy

An 'offensive' innovation strategy is one designed to achieve technical and market leadership by being ahead of competitors in the introduction of new products.[2] Since a great deal of world science and technology is accessible to other firms, such a strategy must either be based on a 'special relationship' with part of the world science–technology system, or on strong independent R and D, or on very much quicker exploitation of new possibilities, or on some combination of these advantages. The 'special relationship' may involve recruitment of key individuals, consultancy arrangements, contract research, good information systems, personal links, or a mixture of these. But in any case the technical and scientific information for an innovation will rarely come from a single source or be available in a finished form. Consequently the firm's R and D department has a key role in an offensive strategy. It must itself generate that scientific and technical information which is not available from outside and it must take the proposed innovation to the point at which normal production can be launched. A partial exception to this generalization is the new firm which is formed to exploit an innovation already wholly or largely developed elsewhere, as was the case with many scientific-instrument innovations. The new small firm is a special category of 'offensive' innovator. The remarks here apply primarily to already established firms, but we may recall the conclusion of chapters 6 and 7 that the importance of the new small innovating firm is related to the reluctance and inability of many established firms to adopt an offensive strategy.

The firm pursuing an 'offensive' strategy will normally be highly 'research-intensive', since it will usually depend to a considerable extent on in-house R and D. In the extreme case it may do nothing but R and D for some years. It will

2. The new product may, of course, be a 'process' for other firms.

attach considerable importance to patent protection since it is aiming to be first or nearly first in the world, and hoping for substantial monopoly profits to cover the heavy R and D costs which it incurs and the failures which are inevitable. It must be prepared to take a very long-term view and high risks. Examples of such an offensive strategy which have been considered in Part One are RCA's development of television and colour television, Du Pont's development of nylon and Corfam, IBM's 360 series, IG Farben's development of PVC, ICI's development of Terylene, Bell's development of semiconductors, Houdry's development of catalytic cracking, and the UK Atomic Energy Authority's development of various nuclear reactors. It took more than ten years from the commencement of research before most of these innovations showed any profit, and some never did so.

The extent to which an offensive strategy requires the pursuit of in-house fundamental research is a matter partly of debate and partly of definition. From a narrow economic point of view it is fashionable to deride in-house fundamental research, and to regard it as an expensive toy or a white elephant. Certainly it can be this, and the advice of many economists and management consultants to leave fundamental research to universities has a kernel of good sense. But it may be too narrow. Certainly some of the most successful 'offensive' innovations were partly based on in-house fundamental research. Or at least the firms who were doing it described it as such, and it could legitimately be defined as research without a *specific* practical end in view (the definition of applied research). However, it was certainly not completely pure research in the academic sense of knowledge pursued without *any* regard to the possible applications. Perhaps the best description of it is 'oriented fundamental research' or 'background fundamental research'. A strong case can be made for doing this type of research as part of an offensive strategy (or even in some cases as part of a defensive strategy).

The straightforward economic argument against in-house fundamental research holds that no firm can possibly do more than a small fraction of the fundamental research which

is relevant, and that in any case the firm can get access to the results of fundamental research performed elsewhere. This over-simplified 'economy' argument breaks down because of its failure to understand the nature of information processing in research, and the peculiar nature of the interface between science and technology. There is no direct correspondence between changes in science and changes in technology. Their interaction is extremely complex and resembles more a process of mutual 'scanning' of old and new knowledge. The argument that 'anyone can read the published results of fundamental scientific research' is only a half-truth. A number of empirical studies which have been made in the United States indicate that access to the results of fundamental research is partly related to the degree of participation (Price and Bass, 1969). Many case studies of innovation show that direct access to original research results was extremely important, although the mode of access varied considerably (Illinois Institute of Technology Research Institute, 1969; Langrish *et al.*, 1972; Wilkins, 1967). In-house fundamental research was obviously important in some of the cases which have been considered in Part One (e.g. nylon and polyethylene), and its role in relation to Bell's discovery and development of the transistor has been discussed in a classic paper by Nelson (1962). It was also important in a significant proportion of the American case studies, for example in GE and Dow. The results of SAPPHO, although not strongly differentiating between success and failure on the basis of fundamental research performance, did suggest a marginal advantage to fundamental research performers (Science Policy Research Unit, 1971 and 1972). It may sometimes be a matter of hair-splitting as to whether research is defined as 'background', 'oriented basic' or 'applied research'. The difficulties in defining and measuring the various categories of R and D are discussed more fully in the Appendix but it must always be remembered that all schemes of classification are to some extent arbitrary and artificial.

Price and Bass (1969) have attempted to measure the relative importance of direct participation as one of the modes

Table 38 Frequency of use of coupling method

Category of coupling	*Suits and Bueche*	*Frey and Goldmann*	*Tanenbaum (MAB)*
indirect[a]	8	5	25
passive availability[b]	28	17	43
direct participation[c]	38	18	40
'gatekeeper'[d]	14	2	6
all 'coupling events'	88	42	114

[a]No direct dialogue between originators and users of new scientific knowledge
[b]Scientists are open to approach but do not initiate a dialogue. Technologists request assistance
[c]Includes inter-disciplinary teams, exchanges and consultants
[d]Gifted individuals assigned the specific function of promoting communication between scientists and engineers
Source: Price and Bass (1969)

of access to original research. They classified 244 'coupling events' in twenty-seven innovation case studies. A 'coupling event' is one which links developments in basic science with technological advances. The results shown in Table 38 indicate that 'direct participation' was involved in forty per cent of the 'events', and 'passive availability' of scientists outside firms was also very important. It is not unreasonable to postulate that here too the effectiveness of communication is to some extent a function of the degree of involvement in basic research.

Most of these studies relate to innovations made by firms which would probably be classified as 'offensive', and tend to confirm the view that in-house oriented fundamental research combined with monitoring activities and consultancy are important modes of access to new knowledge for firms pursuing such a strategy. Price and Bass conclude that:

1 Although the discovery of new knowledge is not the typical *starting point* [my italics] for the innovative process, very frequently interaction with new knowledge or with persons actively engaged in scientific research is essential.

2 Innovation typically depends on information for which the requirement cannot be anticipated in definitive terms and therefore cannot be programmed in advance; instead key information is often provided through unrelated research. The process is facilitated by a great deal of freedom and flexibility in communication across organizational, geographical and disciplinary lines.

3 The function of basic research in the innovative process can often be described as meaningful dialogue between the scientific and technological communities. The entrepreneurs for the innovative process usually belong to the latter sector, while the persons intimately familiar with the necessary scientific understanding are often part of the former.

These findings are extremely important, because it has often been concluded from individual case studies that technical innovations bear no relation to basic research or the advance of scientific knowledge. The results of the American Department of Defence 'Project Hindsight' (Sherwin and Isenson, 1966) and of the Manchester 'Queen's Award' study (Langrish *et al.*, 1972) were often wrongly construed in this way, because they suggested that most of the new products were based on 'old' science. Any major innovation will draw on a stock of knowledge much of which is 'old' in this sense. But the capacity to innovate successfully depends increasingly on the ability to draw upon this whole corpus of structured knowledge, old and new.

The availability of external economies in the form of a highly developed scientific and technological 'infrastructure' is consequently a critical element in innovative efficiency. Although these external economies are to some extent world wide, and to this extent it makes sense to talk of a world 'stock' or 'pool' of knowledge, access to many parts of it is limited. Cultural, educational, political, national and proprietary commercial barriers prevent everyone from drawing freely on this stock as well as purely geographical factors. The ability to gain access to it is an important aspect of R and D management and bears a definite relationship to research performance and reputation. Pavitt's inter-country comparisons of innovative performance (1971) also bear out this conclusion and so too does the second Manchester study by Gibbons and Johnston on the interactions of science and technology (1972).

We may conclude, therefore, both from the results of Price and Bass and from our own survey, that the performance of fundamental research, whilst not essential to an offensive innovation strategy, is often a valuable means of access to new and old knowledge generated outside the firm, as well as a source of new ideas within the firm. Whilst ultimately all firms may be able to use new scientific knowledge, the firm with an offensive strategy aims to get there many years sooner. Even if it does not conduct oriented fundamental research itself it will need to be able to communicate with those who do, whether by the performance of applied research, through consultants or through recruitment of young post-graduates or by other means. This has very important implications for manpower policy as well as for communications with the outside scientific and technological community.

But although access to basic scientific knowledge may often be important, the most critical technological functions for the firm pursuing an offensive innovation strategy will be those centred on experimental development work. These will include design-engineering on the one hand, and applied research on the other. A firm wishing to be ahead of the world in the introduction of a new product or process must have a very strong problem-solving capacity in designing, building and testing prototypes and pilot plants. Its heaviest expenditures are likely to be in these areas, and it will probably seek patent protection not only for its original breakthrough inventions but also for a variety of secondary and follow-up inventions. Since many new products are essentially engineering 'systems', a wide range of skills may be needed. Pilkington's were successful with the 'float glass' process and I G Farben with PVC, largely because they had the scientific capacity to resolve the problems which cropped up in pilot plant work, and could not be resolved by 'rule of thumb'. The same is even more true of nuclear-reactor development work.

There has been a great deal of confusion and misunderstanding over expenditure on R and D in relation to the total costs of innovation. It became fashionable to talk of R and D costs as a relatively insignificant part of the total costs of innovation – at most ten per cent. This view is not supported by any empirical research and is based on a misreading of a United States Department of Commerce report frequently quoted and re-quoted. The small amount of empirical research which has been done on this question indicates that R and D costs typically account for about fifty per cent of the total costs of launching a new product in the electronic and chemical industries. As in so many aspects of industrial innovation it is Mansfield and his colleagues (1971) who got down to the hard task of systematic empirical observation and measurement, rather than plucking generalizations from the air.

This is not to minimize the importance of production planning, tooling, market research, advertising and marketing. All of these functions must be efficiently performed by the innovating firm, but its most important distinguishing feature is likely to be its heavy commitment to applied research and experimental development. As we have seen, this was characteristic of I G Farben, Du Pont, G E, R C A, Bell and other offensive innovators. In the case of the new firm established to launch a new product, the inventor–entrepreneur is himself the living embodiment of this characteristic.

However, in order to succeed in its 'offensive' strategy the firm will not only need to be good at R and D, it will also need to be able to educate both its customers and its own personnel. At a later stage these functions may be socialized as the new technology becomes generally established, but in the early stages (which may last for some decades) the innovating firm may have to bear the brunt of this educational and training effort. This may involve running courses, writing manuals and textbooks, producing films, providing technical assistance and advisory services and developing new instruments. Typical examples of this aspect of innovation are the Marconi school for wireless operators, the B A S F agricultural advisory stations, the I C I technical services for polyethylene and other plastics, the IBM and ICL computer training and advisory services, UKAEA's work on isotopes, and technical education of the consortia and the CEGB.

The 'offensive' innovator will need good scientists, technologists and technicians for all these functions as well as for production and marketing of the new product. This means that such firms are likely to be highly 'education-intensive' in the sense of having an above-average ratio of scientifically trained people in relation to their total employment. The generation and processing of information occupy a high proportion of the labour force, but whereas for the 'traditional' firm this would represent a 'top heavy' and wasteful deployment of resources, these activities are the life-blood of the 'offensive' innovating firm.

'Defensive' innovation strategy

Only a small minority of firms in any country are willing to follow an 'offensive' innovation strategy, and even these are seldom able to do so consistently over a long period. Their very success with original innovations may lead them into a position where they are essentially resting on their laurels and consolidating an established position. They will in any case often have products at various stages of the product cycle – some completely new, others just established and still others nearing obsolescence. The vast majority of firms, including some of those who have once been 'offensive' innovators, will follow a different strategy: 'defensive', 'imitative', 'dependent', 'traditional', or 'opportunist'. It must be emphasized again that these categories are not pure forms but shade into one another. The differences assume particular importance in relation to industry in the developing countries, but thev are important in Europe and America as well.

A 'defensive' strategy does not imply absence of R and D. On the contrary a 'defensive' policy may be just as research-intensive as an 'offensive' policy. The difference lies in the nature and timing of innovations. The 'defensive' innovator does not wish to be the first in the world, but neither does he wish to be left behind by the tide of technical change. He may not wish to incur the heavy risks of being the first to innovate and may imagine that he can profit from the mistakes of early innovators and from their opening up of the market. Alternatively, the 'defensive' innovator may lack the capacity for the more original types of innovation, and in particular the links with fundamental research. Or he may have particular strength and skills in production engineering, and in marketing. Most probably the reasons for a 'defensive' strategy will be a mixture of these and similar factors. A 'defensive' strategy may sometimes be involuntary in the sense that a would-be 'offensive' innovator may be out-paced by a more successful offensive competitor.

Several surveys (Nelson, Peck and Kalachek, 1967) have shown that even in the United States, most industrial R and D is 'defensive' in character concerned primarily with short time horizons and 'improvements' (Table 36). Defensive R and D is probably typical of most oligopolistic markets and is closely linked to product differentiation. For the oligopolist, defensive R and D is a form of insurance enabling him to react and adapt to the technical changes introduced by his competitors. Since the 'defensive' innovator does not wish to be left too far behind, he must be capable of moving rapidly once he decides that the time is ripe. If he wishes to obtain or retain a significant share of the market he must design a model at least as good as the early innovators and preferably incorporating some technical advances which differentiate his product, but at a lower cost. Consequently, experimental development and design are just as important for the 'defensive' innovator as for the 'offensive' innovator. Computer firms which continued to market valve designs long after the introduction of semiconductors could not survive. Chemical contractors which attempted to market a process which was technically obsolescent could not survive either. The 'defensive' innovator must be capable at least of catching up with the game, if not of 'leap-frogging'.

Patents may be extremely important for the 'defensive' innovator but they assume a slightly different role. Whereas, for the pioneer, patents are often a critical method of protecting a technical lead and retaining a monopolistic position, for the 'defensive' innovator they are a bargaining counter to weaken this monopoly. The defensive innovator will typically regard patents as a nuisance, but will claim that he has to get them to avoid being excluded from a new branch of technology. The offensive innovator will often regard them as a major source of licensing revenue, as well as protection for the price level needed to recoup R and D costs. He will fight major legal battles to establish and protect his patent position (RCA with television, ICI with polyethylene, La Roche with tranquillizers, Telefunken with PAL), and typically his receipts from licensing and know-how deals will far exceed his expenditure. (In 1971, ICI had receipts of £13 million and expenditure of £3 million.)

The 'defensive' innovator will probably find it necessary to devote resources to the education and training of his customers as well as his own staff. He will also have to provide them with technical assistance and advice. But these functions may well be less important for the 'defensive' innovators than for the pioneers, as the product will no longer be completely new. On the other hand advertising and selling organizations, the traditional weapons of the oligopolist, will probably be more important, and to some extent technical service to customers will be bound up with this. The oligopolist may well attempt to use a combination of product differentiation and technical services to secure a market share not attainable by sheer originality.

Both the 'offensive' and the 'defensive' innovator will be deeply concerned with long-range planning, whether or not they formalize this function within the firm. In many cases this may still often be the 'vision' of the entrepreneur and his immediate associates, but increasingly this function, too, is becoming professionalized and specialized, so that 'Product Planning' is a typical department for both 'offensive' and 'defensive' innovators. However, the more speculative type of 'technological forecasting' is more characteristic of the 'offensive' innovator, and as we have seen in chapter 7, still has considerable affinities to astrology or fortune-telling. It should

probably still be regarded as a kind of sophisticated war dance to mobilize a faction in support of a particular project or strategy, but increasingly important serious techniques are being developed (Bright, 1968; Beattie and Reader, 1971, Appendix 1, bibliography; Jones, 1969).

The 'defensive' innovator, then, like the 'offensive' innovator, will be a knowledge-intensive firm, employing a high proportion of scientific and technical manpower. Scientific and technical information services will be particularly important and so will speed in decision-making, since survival and growth will depend to a considerable extent on timing. The defensive innovator can wait until he sees how the market is going to develop and what mistakes the pioneers make, but he dare not wait too long or he may miss the boat altogether, or slip into a position of complete dependence in which he has lost even that degree of freedom of manoeuvre which he once possessed. R and D will be geared to speed and efficiency in development and design work, once management decides to take the plunge. Such firms will often describe their R and D as 'advanced development' rather than 'research'.

Most commonly the large multi-product chemical or electrical firm will contain elements of both 'offensive' and 'defensive' strategies in its various product lines, but a 'defensive' strategy is more characteristic of firms in the smaller industrialized countries, which cannot risk an 'offensive' strategy or lack the scientific environment and the market.

The strategy which a firm is able or willing to pursue is strongly influenced by its national environment and government policy. Thus, for example, European firms since the war have generally been unable or unwilling to attempt offensive innovations in the semiconductor industry and their role has been almost entirely 'defensive'. French chemical firms have followed a 'defensive' strategy while German chemical firms have often been 'offensive'. The complex interplay of national environment and firm strategy cannot be dealt with in detail here. But it is important to make the simple but fundamental point that many firms in the 'offensive' group are United States firms, while most firms in the developing countries are 'imitative', 'dependent' or 'traditional', with Europe in an intermediate position. This means that a 'defensive' innovation strategy has been particularly characteristic of European firms since the war. An over-simplified interpretation of Japanese experience since 1900 would be in terms of the movement of an increasing proportion of firms from traditional to imitative strategies, and then to defensive and offensive innovations. Japanese national policy has been designed to facilitate this progression.

A technology policy of this sort involves a gradual change in the 'mix' of STS in the direction of a more R and D-intensive mix. The type of R and D also changes from adaptive to increased originality, but it may require a long period in which most enterprises follow a dependent or imitative strategy, whilst slowly strengthening their technical resources, on the basis of a carefully conceived long-term national policy, involving protection of 'infant technology' as well as the build-up of a wide range of government-supported STS. The precise balance of STS must vary with the size, resource endowment and historical background of each country. But in many developing countries STINFO (Scientific and Technical Information Services), Survey organizations, Standards Institutes, Technical Assistance organizations and Design-Engineering Consultancy organizations capable of impartial scrutiny and feasibility studies for projects involving imported technology are all of critical importance. They can provide the essential Science and Technology infrastructure which enables the STS at enterprise level to function effectively, despite the inevitable limitations in trained scientific and technical manpower. Only a few enterprises will gradually be able to develop first an adaptive and later an original innovative capacity. However, even in the United States the vast majority of firms are 'traditional', 'dependent' or 'imitative' in their strategies. We now turn to a consideration of these alternatives.

'Imitative' and 'dependent' strategies

The 'defensive' innovator does not normally aim to produce a 'carbon' copy imitation of the products introduced by early

innovators. On the contrary he hopes to take advantage of their early mistakes to improve upon their design, and he must have the technical strength to do so. At least he would like to differentiate his product by minor technical improvements. He will try to compete by establishing an independent patent position rather than simply by taking a licence, but if he does take a licence it will usually be with the aim of using it as a spring-board to do better. However, his expenditure on acquisition of know-how and licences from other ('offensive') firms will often exceed his income from licensing. For the 'imitative' firm it will always do so.

The 'imitative' firm does not aspire to 'leap-frogging' or even to 'keeping up with the game'. It is content to follow way behind the leaders in established technologies, often a long way behind. The extent of the lag will vary, depending upon the particular circumstances of the industry, the country and the firm. If the lag is long then it may be unnecessary to take a licence, but it still may be useful to buy know-how. If the lag is short, formal and deliberate licensing and know-how acquisition will often be necessary. The imitative firm may take out a few secondary patents but these will be a by-product of its activity rather than a central part of its strategy. Similarly, the imitative firm may devote some resources to technical services and training but these will be far less important than for the innovating firms, as the imitators will rely on the pioneering work of others or on the socialization of these activities, through the national education system. An exception to this generalization might be in a completely new area (for example in a developing country) when neither imports nor the subsidiary of an innovating firm have opened up the market. The enterprising 'imitator' may aspire to become 'a defensive' innovator, especially in rapidly growing economies.

The 'imitator' must enjoy certain advantages to enter the market in competition with the established innovating firms. These may vary from a 'captive' market to decisive cost advantages. The 'captive' market may be within the firm itself or its satellites. For example, a large user of synthetic rubber, such as a tyre company, may decide to go into production on its own account. Or it may be in a geographical area in which the firm enjoys special advantages, varying from a politically privileged position to tariff protection. (This will be the typical situation in many developing countries.) Alternatively or additionally, the imitator may enjoy advantages in lower labour costs, plant investment costs, energy supplies or material costs. The former are more important in electrical equipment, the latter in the chemical industry. Lower material costs may be the result of a natural advantage or of other activities (e.g. oil refineries in the plastics industry). Finally, the imitator may enjoy advantages in managerial efficiency and in much lower overhead costs, arising from the fact that he does not need to spend heavily on R and D, patents, training, and technical services, which loom so large for the innovating firm. The extent to which imitators are able to erode the position of the early innovators through these advantages will depend upon the continuing pace of technological change. The early innovators will try to maintain a sufficient flow of improvements and new 'generations' of equipment, so as to lose the 'imitators'. But if the technology settles down, and the industry becomes 'mature', they are vulnerable and may have to innovate elsewhere. Du Pont's decision to move right out of the rayon industry despite their technical strength is a good example of strategic planning of this kind. Hirsch (1965) has summarized the characteristics of the product cycle which may permit 'imitators' to compete (Table 39 and Figure 9). The extent to which they are actually able to do so, particularly in developing countries, is strongly influenced by institutional factors and government policies.

Unless the 'imitator' enjoys significant market protection or privilege, he must rely on lower unit costs of production to make headway. This will usually mean that in addition to lower overheads, he will also strive to be more efficient in the basic production process. He may attempt this by process improvements, but both static and dynamic economies of scale will usually be operating to his competitive disadvantage, so that good 'adaptive' R and D must be closely linked to manufacturing. Consequently production engineering and design

Table 39 Characteristics of the product cycle

Characteristics	*Cycle phase* Early	Growth	Mature
technology	short runs rapidly changing techniques dependence on external economies	mass production methods gradually introduced variations in techniques still frequent	long-runs and stable technology few innovations of importance
capital intensity	low	high, due to high obsolescence rate	high, due to large quantity of specialized equipment
industry structure	entry is know-how determined numerous firms providing specialized services	growing number of firms many casualties and mergers growing vertical integration	financial resources critical for entry number of firms declining
critical human inputs	scientific and engineering	management	unskilled and semi-skilled labour
demand structure	sellers' market performance and price of substitutes determine buyers' expectations	individual producers face growing price elasticity intra-industry competititon reduces prices product information spreading	buyers' market information easily available

Source: Hirsch (1965)

are two technical functions in which the imitator must be strong. Even if he is making carbon copies under licence, the imitator cannot afford to have high production costs unless he has high tariff protection. He will also wish to be well-informed about changes in production techniques and in the market, so that scientific and technical information services are another function which is essential for the 'imitator' firm. The information function is also important for the selection of products to imitate and of firms from which to acquire know-how. It is clear that in all of this the would-be imitator in the typical developing country may be severely handicapped by local circumstances, unless national policies are carefully designed to facilitate technical progress.

A 'dependent' strategy involves the acceptance of an essentially satellite or subordinate role in relation to other stronger firms. The 'dependent' firm does not attempt to initiate or even to imitate technical changes in its product, except as a result of specific requests from its customers or its parent. It will usually rely on its customers to supply the technical specification for the new product, and technical advice in introducing it. Most large firms in industrialized countries have a number of such satellite firms around them supplying components, or doing contract fabrication and machining, or supplying a variety of services. The 'dependent' firm is often a sub-contractor or even a sub-sub-contractor. Typically, it has lost all initiative in product design and has no R and D facilities. The 'small' firms in capital-intensive industries are often in this category and hence account for hardly any innovations (see chapter 6).

The pure 'dependent' firm is in effect a department or shop of a larger firm, and very often such firms are actually taken over. But it may suit the large firm to maintain the client relationship, as sub-contractors are a useful 'cushion' to mitigate fluctuations in the work load of the main firm. The 'dependent' firm may also wish to retain its formal independence as the owners may hope they will ultimately be able to change their status by diversification or by enlarging their market. They may in any case prize even that limited degree of auto-

production factors	product cycle phase		
	new	growth	mature
management	2	3	1
scientific and engineering know-how	3	2	1
unskilled labour	1	2	3
external economies	3	2	1
capital	1	3*	3*

Figure 9 The relative importance of various factors in different phases of the product cycle.
The purpose of the blocks is simply to rank the importance of the different factors, at different stages of the product cycle. The relative areas of the rectangles are not intended to imply anything more precise than this. * Considered to be of equal importance
Source: Hirsch (1965)

nomy which they still enjoy as a satellite firm. In spite of their apparently weak bargaining position, they may enjoy good profits for considerable periods, because of low overheads, entrepreneurial skill, specialized craft knowledge or other peculiar local advantages. Even if they are 'squeezed' pretty hard by their customers, they may prefer to endure long periods of low profitability rather than be taken over completely. Although bankruptcies and take-overs may be common, there is also a stream of new entries.

'Traditional' and 'opportunist' strategies

The 'dependent' firm differs from the 'traditional' in the nature of its product. The product supplied by the 'traditional' firm changes little, if at all. The product supplied by the 'dependent' firm may change quite a lot, but in response to an initiative and a specification from outside. The 'traditional' firm sees no reason to change its product because the market does not demand a change, and the competition does not compel it to do so. Both lack the scientific and technical capacity to initiate product changes of a far-reaching character, but the 'traditional' firm may be able to cope with design changes which are essentially fashion rather than technique. Sometimes indeed, this is its greatest strength.

'Traditional' firms may operate under severely competitive conditions approximating to the 'perfect competition' model of economists, or they may operate under conditions of fragmented local monopoly based on poor communications, lack of a developed market economy, and pre-capitalist social systems. Their technology is often based on craft skills and their scientific inputs are minimal or nonexistent. Demand for the products of such firms may often be very strong, to some extent just *because* of their traditional craft skills (handicrafts, restaurants and decorators). Such firms may have good survival power even in highly industrialized capitalist economies. But in many branches of industry they have proved vulnerable to exogenous technical change. Incapable of initiating technical innovation in their product line, or of defensive response to the technical changes introduced by others, they have been gradually driven out. These are the 'peasants' of industry.

An industrialized capitalist society includes some industries which are predominantly 'traditional', and others characterized by rapid technical innovation. It has been argued that an important feature of the twentieth century has been the growth of the 'research-intensive' sector. But it is a matter of conjecture and of policy as to how far this change may continue. It is a complex process, since sometimes the very success of a technical innovation may lead to standardized mass production of a new commodity with little further technical change or research for a long time. Usually, however, the industries generated by R and D have continued to perform it, so that the balance has gradually shifted towards a more research-intensive economy, and a higher rate of technical change. It is the contention of this book that this is one of the most important changes in twentieth-century industry, but it must be seen over a long time-perspective.

This shift has been less the result of any conscious central government strategy (although government policies have increasingly tended to favour this change) than the outcome of an infinite series of adaptive responses by firms to external pressures at home and abroad, and of attempts to realize the dreams of inventors. The efforts of firms to survive, to make profits and to grow have led them to adopt one or more of the strategies which have been discussed. But the variety of possible responses to changing circumstances is very great, and to allow for this element of variety I have included one other category, described as an 'opportunist' or 'niche' strategy. There is always the possibility that an entrepreneur will identify some new opportunity in the rapidly changing market, which may not require any in-house R and D, or complex design, but will enable him to prosper by finding an important 'niche', and providing a product or service which consumers need, but nobody else has thought to provide. Imaginative entrepreneurship is still such a scarce resource that it will constantly find new opportunities, which may bear little relation to R and D, even in 'research-intensive' industries.

Innovation strategy in developing countries

Those firms which adopt a strategy of offensive or defensive innovation have gradually 'learned' how to innovate. But there is no recipe which can ensure success and intense controversy still surrounds the important ingredients. The fact that they are often innovating on a world market increases the uncertainty which they confront, and has led increasingly to the involvement of government to subsidize R and D, to create appropriate infrastructures and to diminish market uncertainty. Economic policy inevitably becomes enmeshed with policy for science and technology. These problems are particularly acute for the developing countries.

An underdeveloped economy may for a while base itself mainly or entirely on an industrial structure which relies on dependent and traditional strategies. If it does so, it is likely to remain extremely poor and backward. One possible alternative is the Chinese path but this is difficult for smaller and weaker nations. Even a successful imitative strategy, although it may lead to industrial development, will reach a point when export competitiveness in labour costs may increasingly conflict with the goal of higher *per capita* incomes. In such a case, the Japanese strategy of moving up the scale steadily may be the most appropriate, and the distinctive feature of the Japanese success has been the way in which government policies have underpinned the efforts of management at enterprise level. However, the Japanese success in raising *per capita* incomes rapidly and in strengthening the technical capacity of the economy, has been accompanied by considerable degradation of the environment and other unpleasant consequences of rapid industrial change. It is to these problems of national and international policy for innovation and for science and technology that we turn in the final chapter, but here it will be useful to consider very briefly some of the problems of developing countries in the context of the analysis in this chapter.

Innovative effort which is directed towards satisfying the market needs of consumers tends to be biased towards higher income groups for several reasons. Most obviously, of course, poorer people cannot afford much more than the bare necessities and they cannot afford to pay the premium prices which are often inevitable in the early stages of a new-product. In the jargon of economics this means that new products tend to have a high income-elasticity. Wealthier people and richer firms can afford to indulge new tastes and to take more risks.

It is on a global scale that the most extreme effects of world-wide inequality in incomes are apparent. The bias in the world research innovation system is so great as to constitute a danger to the future of human society. The elementary facts are by now universally known. The Lorenz curve of world income distribution shows a skewness far more extreme than that of any individual country. Not nearly so well known is the fact that 98 per cent of the world's R and D is conducted in the industrialized countries, and that it is overwhelmingly and quite naturally directed towards satisfying demands in those countries (United Nations, 1970). This means that very little of the world's R and D is in fact directly concerned with the elementary needs of the majority of the world's inhabitants. And here the bias in the *capital* goods sector is often of the greatest importance. The need for innovations in both capital goods and consumer goods designed specifically for the needs of the developing countries is very great; yet the innovation mechanism of the world market is biased overwhelmingly towards the high income countries. The bias is so strong that some European companies now actually launch their innovations first on the U S market. The need for labour-intensive innovations can never be met in this way, and the need for new policies is urgent. The indiscriminate import of technologies developed for entirely different markets through the operations of multi-national corporations may have disastrous employment and other social effects in weak poor countries (Cooper, 1973).

The import of foreign technology is often discussed in terms of two equally impracticable extremes. On the one hand, a position of complete autarchy in science and technology, of striving to be completely independent in every single branch of research and development, would be ruinously expensive and almost impossible for all but the largest super-powers. The mechanisms for the international transfer of technology are of the greatest importance for policy-makers in the developing countries. Every country stands to gain enormously from international interchange and division of labour in world science and technology. On the other hand, an international division of labour in science and technology which is so one-sided that it leaves large areas virtually denuded of independent scientific capacity is equally unacceptable. Even on the narrowest economic grounds it is highly inefficient, and is only recommended by those economists who have had no practical contact with the problems of technology transfer. Simply to assimilate any sophisticated technology today, and operate it efficiently, requires *some* independent capacity for R and D, even if this is mainly adaptive R and D. Not just in agriculture, but also in manufacturing, the variety of local conditions is so great that simple 'copying' is often ruled out. Thus in many countries the capacity to receive technology from outside imperatively requires some independent indigenous science base. To solve the innumerable local problems of soil, materials, environment, skills and climate requires that the indigenous base should grow and flourish.

What is desirable on economic grounds is even more so on cultural and political grounds. While *some* scientific and technical capacity is necessary for assimilation of the results of foreign research and technical progress, it is undoubtedly possible to get by with a far smaller commitment than that made in the super-powers or even in several West European countries. Obviously the *size* of a country has a very great bearing on this question and will affect the degree of specialization which is necessary. Heavy reliance on imported technology is an inescapable necessity for most countries in the world. The economic consequences of this situation are perhaps not too serious, but the political and cultural consequences are very great. One must therefore expect that the smaller countries, as well as the developing countries, will lay increasing stress on equitable international arrangements for access to world science and technology. The attempt to establish more expensive 'autarchic' R and D is to some extent a defensive reaction against the political dangers of potential lack of access. Only in proportion to the growth of mutual trust, and a genuinely international policy, will the achievement of more equitable and mutually beneficial international division of labour in science and technology be possible. Such a division must in any case be based in principle on all countries *contributing* to as well as *drawing* from the world stock of knowledge.

The implications of this are complex for technology and multinational corporations but relatively clear for fundamental science. The greatest significance of fundamental research is that it provides a multi-purpose general knowledge base on which to build a wide range of scientific and technical services. Every country without exception requires such a base, even if only on a very small scale. Without it there cannot be any independent long-term cultural, economic or political development. One of the main objectives of world policy for science and technology should be to build and sustain an indigenous scientific capacity throughout the developing world. The Canadian International Development Research Centre is an important step towards the reorientation of world science in this direction (IDRC 1972). The fact that a major industrialized country was ready to devote resources to strengthen R and D in developing countries in this way is a hopeful sign.

But the need for a far greater redistribution of world scientific and technical resources in favour of the developing countries is urgent.

Conclusions

In Part One of this book it was argued from historical evidence that the professionalization of the R and D process was one of the most important social changes in twentieth-century industry. In Part Two it has been argued that the requirements of successful innovation and the emergence of an R and D establishment within industry have profoundly modified patterns of firm behaviour. This means that it is no longer satisfactory (if it ever was) to explain firm behaviour exclusively in terms of response to price 'signals' in an external environment, and adjustment towards an 'equilibrium' situation. World technology is just as much a part of the firm's environment as the world market, and the firm's adaptive responses to changes in technology cannot be reduced to predictable reactions to price changes. This makes things difficult for economists. It means that they must pay much more attention to engineers and to sociology, psychology and political science. Economists have an elegant theory which is confronted with a very untidy and messy reality. Their theory was and is an important contribution to the explanation and prediction of many aspects of firm behaviour, but it is not self-sufficient and attempts to make it so can only lead to sterility.

The sketchy discussion in this chapter is not intended as an alternative theory of firm behaviour. Such a theory requires a greater integrative effort in the social sciences than I am capable of. But it is intended to indicate the kind of issues which must be embraced by any theory which seeks to explain the firm's adaptive response to technological change, as well as to price changes in its factor inputs and the market for its products. There are encouraging indications that social scientists from several disciplines, including economists, are beginning to tackle the development of a more comprehensive and satisfactory theory of the firm. Particularly notable is the work of Mansfield (1968a and b; *et al.*, 1971), Nelson (1962, 1971) and Gold (1971) in the United States, who have made outstanding empirical studies of firm behaviour in relation to innovation. Nelson's new work with Winter may at last bridge the chasm which has developed between the empirical findings discussed here and macroeconomic theory.

Much better known, of course, is the work of Galbraith (1969), who has shown great awareness of the relevance of technological innovation for economic theory. His emphasis on the increased specialization and complexity of technology and the emergence of a 'techno-structure' is fully consistent with the argument of Part One, but there are some important differences of interpretation which are discussed in the next chapter.

Alternative Energy Technologies and Third World Rural Energy Needs: A Case of Emerging Technological Dependency

Kurt Hoffman

MOD 13

The developing countries are becoming increasingly aware that renewable energy sources may have the potential to meet a sizeable percentage of their future energy requirements, particularly in the rural areas. The technology needed to convert the energy potential of the sun, the wind and biomass into useable energy, however, is still in the relatively early stages of development. Consequently, some Third World countries, assisted by the international agencies, are beginning to mount a major R & D effort aimed at developing the necessary systems for the conversion and supply of energy from renewable sources.

The developing countries are not the only countries interested in renewable energy sources. Many of the advanced industrial countries have begun sizeable R & D programmes intended to develop alternative energy conversion systems that are technically and economically feasible. The private sector already plays a major role in this effort. A major objective of these efforts is to market the new systems in the Third World. Although the trends are just beginning to emerge, it seems likely that the West will be able to develop and market a wide range of alternative energy techniques long before Third World R & D efforts produce satisfactory results.

If this is the case, there may be strong arguments for the Third World to use Western renewable energy systems instead of developing their own indigenous technical solutions to the problems. The danger of this situation is that the developing countries may once again find themselves in a position of technological dependence vis-à-vis the West which could conceivably parallel their high

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degree of dependence on the West for conventional energy systems. The developing countries, particularly the rural poor, may consequently incur significantly higher long and short-term costs if they depend solely on the West to supply their technology requirements. Given the open nature of the field, however, a number of policy options are open to the developing countries which would allow them to respond to the current dependency-creating situation in the short term and to develop the necessary technological capabilities to meet their needs in the longer term. It remains to be seen, however, if the rural energy problem is at all amenable to technical solutions, either foreign or indigenous, or whether it is the result of more fundamental conditions of national or international inequality.

Section I of this paper briefly discusses the nature and extent of Third World dependency on Western electric power technology. Section II then outlines the early trends in the approaches of Third World governments to the rural energy problem which seem to be leading them, perhaps unwisely, to place a good deal of emphasis on technical solutions. Section III sets out the evidence of the involvement of the advanced industrial economies in alternative energy technologies and looks at the role of government, the private sector, and of aid agencies in this effort. Section IV discusses the potential impact of these Western activities on Third World undertakings. Finally, Section V briefly discusses how the developing countries might try to structure their policies in this area.

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I. TRENDS IN ENERGY INVESTMENT IN THE THIRD WORLD

The prime objective of most developing countries in the energy sector is to maintain and, if possible, to increase the supply of conventional energy needed to meet their development objectives. Third World nations appear to be committed to a programme of heavy investment in large-scale electricity supply systems. Although the majority of people in the Third World still depend on traditional fuels, between 60-80% of all public sector energy investments in

developing countries are usually directed towards increasing electric power capacity, a considerable proportion of which is used to meet the needs of the urban/industrial sector (Hayes 1977; World Bank 1975).

This tendency to invest in electricity supply has been influenced by a number of factors, the most frequently heard being economic and technical arguments for large-scale, centralized electricity supply systems which are most suited to meet urban energy requirements.

Secondly, many Third World countries are attempting to develop an industrial structure that is largely based on Western technology. Western systems of production are characterized by a high degree of energy consumption per unit of output which, in turn, has necessitated investment in electricity supply (Brookhaven 1978). Thirdly, urban areas in the Third World have experienced extraordinarily high rates of population growth which have placed severe demands on the public sector for increased supplies of energy. Fourthly, most developing countries have a highly skewed pattern of income and wealth distribution. The economic and political power exercised by the elite groups who are concentrated in urban centres, partly explains the priority given to urban energy supply, for many of the same reasons that other infrastructural investments in health, education and transportation have been directed primarily at the urban sector (Lipton 1977; Navarro 1973). Finally, national and international aid agencies have been influenced by Western patterns of energy supply and, consequently, have tended to confine their energy capital loans to centralized electricity production and distribution systems (Hayes 1977).

This confluence of factors has had the obvious result that the rural areas have not received a share of investment in electricity supply proportionate to the population living there. It has been estimated that only 12% of all rural areas in the Third World have access to electricity, with a slight variation between continents — 23% in Latin America, 15% in Asia, 15% in the Middle East and 4% in Southern Africa (World Bank 1975).

Another less widely known result of this pattern of energy investment is that developing countries are now highly dependent upon the West for the supply of most of their conventional energy systems. As in other sectors, this state of technological dependence can be very costly, both in terms of foreign exchange, and because the developing countries may be prevented from developing their own capability in the area' (Patel 1974; UNCTAD 1975). Their dependency for electric power technology and other commercial energy systems has been particularly well-documented in three recent UNCTAD studies and in work carried out by the Science Policy Research Unit of the University of Sussex (UNCTAD 1979; Newfarmer 1978; Epstein and Mirow 1977; Surrey and Cheshire 1972; Surrey, Buckley and Robson 1978).[2]

Developing countries acquire their electric power technology primarily from Western private sector firms. Exports to the Third World already account for a significant percentage of sales by the large transnational electric power equipment producers which dominate the industry.[3] Japanese and US firms, for example, supply over one-third of their total exports of $13 billion to developing countries, while for all Western producers, the Third World accounts for over 25% of total exports of heavy electrical power equipment.

This concentration is even higher for particular product lines: 91% of West Germany's hydraulic turbine production and 44% of Italy's hydraulic generators are sold to poor countries (Newfarmer 1978; Epstein and Mirow 1977), figures which are significantly higher than those for similar commodities, where the Third World share of exports is usually around 10%. Most of the major transnational heavy electrical equipment producers (TNCs) belong to an international cartel called the International Electrical Association,[4] which allegedly allocates Third World markets among TNCs, and also decides the prices that members may quote to prospective buyers for electrical power technology. There is evidence that these prices are sometimes significantly higher than those paid by the developed countries.[5]

In the advanced economies, the electric power equipment industry has recently been plagued by problems of excess capacity which lead the dominant firms to pursue a policy of exporting to Third World markets. This is a reversal of their earlier efforts to set-up subsidiaries in the larger developing countries. These more industrially-advanced developing countries, which have sizeable domestic markets, have managed to build up some indigenous technological capability in this sector.

In Brazil, the TNCs now appear to be following a policy that is designed to eliminate or at least to drastically reduce local production capacity in order to supplant locally-manufactured equipment with imports from the parent companies.[6] These practices may prevent Brazilian electrical power equipment firms from expanding their output to meet increasing domestic demand, resulting in short-term foreign exchange costs for increased imports and the loss of potential revenue for local firms. The decline in local production capacity implies that a more significant cost to Brazil could be the resultant loss of indigenous technological capability associated with the production and installation of electric power equipment. Lack of comparable evidence makes it impossible to determine whether Brazil is a typical case among the larger industrialized developing countries. If it is, loss of this capability or the inability to develop it in a crucial sector such as electric power equipment could have a detrimental impact as Third World demand for electricity continues to grow.

II. THIRD WORLD APPROACHES TO ALTERNATIVE ENERGY TECHNOLOGY

It is not surprising that the degree of government concern with rural energy needs has been relatively limited, but this has become considerably more widespread in recent years throughout the Third World. As a result, policymakers have increasingly focussed their attention on the political contribution to rural energy supply from renewable energy sources.

An argument that is now frequently endorsed by a number of developing countries and international institutions is that, because these countries are well-endowed with renewable energy resources, particularly solar, wind and biomass, they are eminently suited to be the first countries to 'enter the solar age' and to derive a major portion of their energy needs from renewable sources (Hayes 1978; NAS 1976). An additional argument is that because alternative energy systems have the potential to be small-scale and low-cost, they are most appropriate to the rural areas which suffer the most severe energy shortages. Consequently, it is reasoned, Third World nations should make a major effort to develop alternative energy technologies suitable for use in the rural areas.

It is on the basis of these arguments that some developing countries have begun to move into R & D on alternative energy systems for both production and consumption. Although it is impossible at this time to estimate the amount of resources being devoted to alternative energy R & D within the Third World, we are beginning to get a better idea of the degree of institutional involvement in this work. James Howe has recently estimated that there are nearly 200 programmes of research worldwide on small-scale energy projects, with 87% concerned with technology development, and some 79 of which are located in the Third World (Howe 1978). The overwhelming bulk of this research is on various aspects of solar energy use, 63 countries being reputed to have research programmes that total over $500 million (Agarwal 1978). Even though exact figures are not available, we know that extensive R & D work is also being carried out by Third World institutions on biogas, wind power, and various aspects of wood as a fuel (Miccolis 1978; Powell 1978; Schmidt 1977; Githinge 1978).

The degree of interest is still relatively small, but there is every indication that the developing countries will significantly expand their efforts in this area. Many of them have already allocated R & D funds, established research institutes, and created new administrative apparatuses to oversee work in this area, but few have developed a comprehensive strategy to direct their efforts.[7] Very little information is available as to the effectiveness of this R & D, but it appears that these un-coordinated efforts have resulted in the inefficient expenditure of scarce research funds (Barnett 1978).

Many of the early government-funded R & D programmes had little notion of the comparative advantages and disadvantages of meeting rural energy needs with different technologies (Disney 1976; Pyle 1978; Barnett 1978), while insufficient attention was given to the socio-cultural factors that might affect the acceptance and diffusion of new systems in rural areas (Moulik and Srivastava 1978). Another aspect of the problem is that both India and South Korea have committed sizeable resources to subsidize the installation of biogas plants that can only be used by a small, relatively well-off fraction of the rural population and which may already be technically obsolete (Marsdon 1976; Barnett 1978).

Many of these problems could be expected since the developing countries are still in the initial stages of their research efforts. As work continues in this field and as channels of information exchange are opened-up, some of the difficulties will disappear. Nevertheless, it seems that some of these countries are opting for technique-centred solutions to their rural energy problems, and a number of trends can be observed which may become crucial in determining the future ability of developing countries to increase the energy so urgently needed in the rural areas.

Firstly, the reasonably strong emphasis placed on technical R & D has sometimes not been based on adequate understanding of the socio-economic factors that lie at the root of rural energy problems. Some R & D is necessary, of course, but this should take place within an overall rural energy policy framework which encompasses technical as well as economic and cultural factors. If the underlying inequalities in wealth and income distribution in the rural sector persist, then technical solutions will have very little effect in ameliorating the problems. The information base that is needed in order to devise comprehensive policies in the Third World is slowly being generated, but the extent to which this information will actually be used in the formulation of policies has yet to be seen.

Secondly, although there has been a good deal of speculation about the role of renewable energy sources in meeting rural energy demand, very little reliable data is available with which to assess the magnitude of the impact. Considerable technical obstacles still need to be overcome before efficient and economic conversion systems can be developed. In addition, the sheer size of the rural sector and the complex factors that affect the diffusion of new ideas and techniques make it *a priori* unlikely that renewable sources will make much of a contribution in the short term.

In fact, the major rural energy problem likely to face many Third World countries over the next 10 years may centre around the crucial role of fuelwood, which is the dominant energy source in the rural areas of many African and Asian countries (Powell 1978; Earl 1975; French 1978; Ernst 1977). Consumed as firewood and charcoal, it accounts for 96% of *all* energy consumed in Tanzania, 91% in Nigeria and 90% in Uganda. These extremely high levels of consumption are thought to be a contributing factor to the rapid deforestation now occurring in the Third World (Eckholm 1975). In fact, the World Bank estimates that much of the forests in developing countries will virtually disappear in as little as 40 years (World Bank 1978). Such estimates should be treated with caution, of course, but the environmentally catastrophic trend towards deforestation that is taking place does suggest that developing countries should be formulating long-term strategic policies to deal with the problems this situation may create. There is thus every reason to believe that renewable energy sources could play a major role in the longer term, but decisions must be taken in the very near future to ensure that the developing countries will have the technical means with which to convert renewable sources into useable energy and to make it available to their rural populations.

Finally, we have seen that some developing countries are moving in this direction even if the efforts so far are fairly limited, haphazard, and un-coordinated. These Third World efforts are accompanied by calls for intensified activity on the part of the Western countries to being their scientific and technical resources to bear to generate technical solutions to the energy needs of rural areas (Lawand 1976; Usmani 1978; US National Research Council 1978; Ramakumar 1977). Certainly there are technical problems to be overcome in this area which require a major R & D effort. The solution of these problems could yield significant benefits. As will be discussed in the next section, the advanced industrial countries are already engaged in sizeable R & D effort on renewable energy technology. The objectives of Western private and public sector institutions in investing in alternative energy R & D, however, differ significantly from those of the developing countries — the public sector is concerned to shift reliance of the economy away from finite fossile fuels to renewable sources, while the private sector is interested primarily in producing saleable products which will generate a fair rate of return.

The results of this activity may not be directly applicable to developing countries. What is certain, however, is that the developing countries must remain aware of Western R & D activities and should adjust their rural energy and technology strategies accordingly.

III. DEVELOPED COUNTRY INTEREST IN ALTERNATIVE ENERGY TECHNOLOGIES

In the advanced countries, interest in renewable energy has been evolving gradually over the past decade. It originated in the 1960s largely with 'counter culture' groups operating outside the government and the private sector. Since the early 1970s, however, interest has spread so widely that alternative energy technologies are now the subject of major public and private investment efforts. In the international context, the EEC and various national and international aid agencies are also beginning to earmark funds for projects in this area.

It is too early to assess whether or not this government support for renewable energy sources is a positive development for the West

fossil fuels. As we shall see, however, this situation has a number of important ramifications for the efforts of developing countries to make more use of their renewable energy resource endowments. In this section we look at the efforts in this area of the government sector, private industry and the aid agencies.

Government Sector

The support of Western governments for R & D into alternative energy systems is still at an early stage, but the amounts being spent (illustrated in Table 1), already swamp the effort of developing countries. Nevertheless, they are still much less than allocations for conventional energy R & D.

Since the issue of the International Energy Agency's 1977 report, a number of governments have substantially increased their R & D budgets for renewable energy for the 1978-80 period. As might be expected, the USA now has the largest programme of support: under the newly revamped Department of Energy, budget allocations to the Division of Solar Energy have risen from $1.2m in 1971 to an estimated $800m in 1980 (Margetts 1978; US Department of Energy 1978).

A number of other industrial countries have recently announced sizeable investments in R & D on alternative energy. England, France, Denmark and Canada have all allocated more than $10 million for work over the next three years, while the R & D programmes of West Germany, Sweden and Japan are now budgeted at between $20 million-$60 million for the same period (Ministère de L'Industrie 1977; Federal Ministry 1977, 1978; Hinrichsen 1978; UK Department of Energy 1978; *Planned Innovation* 1978). There has tended to be some specialization between these countries, with Denmark investing heavily in wind technology, West Germany and France in solar energy, and the UK opting to develop wave energy.

The objectives of the developed countries are obvious — to promote increased use of renewable energy resources within the domestic economy. A crucial component of some government strategies is the creation of a viable private sector effort in the production and marketing of appropriate technologies.[8] Domestic consumption is envisioned as the major market in the long run by the Western governments, but there are clear indications that overseas markets, particularly in the developing countries, are thought to of-

Table 1. 1977 Government Energy R, D & D Budgets (Current US $ million)

Country / enewable nergy Sources	Canada US$	Canada %*	Denmark US$	Denmark %*	Germany US$	Germany %*	Italy US$	Italy %*	Japan US$	Japan %*	Netherlands US$	Netherlands %*	Spain US$	Spain %*	Sweden US$	Sweden %*	UK US$	UK %*	USA US$	USA %*
otal Non-conventional nergy R & D	6.5	5.3	2.4	14.2	14.4	2.4	7.6	2.8	17.7	3.3	5.3	4.8	6.2	14.5	6.6	11.3	4.5	1.9	229.2	8.1
· Solar	4.9	4.0	0.8	4.7	11.0	1.8	2.5	0.9	5.7	1.1	2.4	2.2	2.9	6.8	2.5	4.3	1.9	0.8	146.8	5.2
· Wind	0.9	0.7	1.2	7.1	2.5	0.4	0.1	—	0.0	0.0	2.4	2.2	0.3	0.7	1.8	3.1	0.2	0.1	15.0	0.5
· Ocean	—	—	—	—	—	—	—	—	0.6	0.1	—	—	—	—	0.3	0.4	1.7	0.7	9.5	0.3
· Biomass	0.4	0.3	0.1	0.4	—	—	—	—	0.3	0.1	0.4	0.4	0.3	0.7	1.4	2.3	0.4	0.2	4.5	0.2
· Geothermal	0.3	0.2	0.4	2.4	0.9	0.2	5.0	1.9	11.1	2.1	0.1	0.1	2.7	6.3	0.7	1.2	0.3	0.1	53.4	1.9
otal Govt. nergy R & D udget	121.0	100	16.9	100	601.2	100	264.2	100	529.9	100	109.7	100	42.8	100	58.6	100	234.6	100	2800.0	100

ource: Extracted from a report by the International Energy Agency, 1977.
* = % of total Government Energy R & D Budget on all Sources of Energy.

fer excellent short-term prospects for a fairly wide range of alternative energy systems now being developed in the private sector with government help (US Department of Energy 1978; Ministère de L'Industrie 1977). It is reasoned that the more or less established demand for such technologies in overseas markets will provide an important stimulus to the nascent alternative energy sector and will help to maintain the commercial viability of the technologies until the domestic market is more fully developed.

This commercial orientation has been most explicitly articulated by the US Department of Energy's Division of Solar Technology, responsible for administering the American programme. The emphasis of American funding activities has been to develop what are termed 'early impact' alternative energy systems, i.e. technologies whose commercial viability can be brought to fruition within a relatively short period of time. Recognition of the importance of Third World markets in this early period of commercialization has caused a certain degree of explicit attention to be given to the development of technologies potentially useful to the Third World.

There are two programmes whose main objectives are to promote the commercialization of US technology throughout the world, one of them within, or connected to, the DOE's Office of International Affairs and explicitly concerned with energy development in less developed countries.

The second programme is the Solar Technology Transfer Programme, the main objective of which is to facilitate the transfer of proven technologies from the Division's technical R & D programmes to the private sector. One of its elements is to develop an international programme component which can directly or indirectly assist an earlier, practical and cost-effective deployment and commercialization of solar energy in America and throughout the world (US DOE, Solar Technology Transfer Programme 1980).

The R & D programmes on Wind, Solar, Photovoltaic Electricity and Biomass all have projects aimed specifically at developing technologies for use by so-called 'isolated communities' in the US which may also have application in rural villages in developing countries. For example, the Biomass Programme is funding work on the use of sugar cane and tropical grass as feed stock for biogasification (Ward 1978; US Department of Energy 1978). Within this effort, it is likely that all options which are deemed technically viable will be examined for their commercial potential for these overseas markets. This commercialization effort would probably include systems which are both 'appropriate' and 'inappropriate' to Third World countries.

Other Western public sector agencies are also following a policy of active collaboration with the private sector to develop Third World export markets. This collaboration takes several forms: participation in joint R & D programmes, establishing pilot projects in developing countries, or granting of government subsidies to exporters of technologies.

SOFRETES, the French state-supported solar energy company whose commercial activities so far have been oriented primarily towards the Third World, has entered into a series of collaborative R & D efforts with major private sector firms totalling 'several millions of US dollars over a period of three years' (Clemot 1978).[9]

Since 1962, SOFRETES has concentrated on developing autonomous water pumping equipment using solar energy. It has successfully developed this solar pump and since 1968 has marketed 1KW power stations and larger units (up to 30KW and 70KW) in the Arab Emirates, Brazil, Cameroon, Upper Volta, Cape Verde Islands, India, Mali, Mexico, Mauritius, Niger, Senegal and Chad. At least 60 1KW stations have been sold to these countries and all have been subsidized by the French government in an explicit attempt to develop a market for French technology. According to SOFRETES, the potential market in Mexico alone for these small pumps is expected to run into the thousands (Clemot 1978). The distorting effect of the subsidy makes it difficult to assess whether such optimism is justified. Casual observations give the impression that significant technical and economic problems still need to be solved.[10]

In West Germany, the Federal Ministry for Research and Technology (BMFT) is responsible for alternative energy programmes, and has recently increased its efforts to collaborate with 'German research institutions and firms with partners in non-European countries...'. German public/private sector projects have been established successfully in Egypt, India, Iran, Jordan, Mexico and Niger, most of them being pilot projects designed to demonstrate the feasibility of solar-based energy supply systems developed in West Germany (Federal Ministry 1978).

This pattern of collaboration in the West between the private and the public sector is clearly intended by the governments to provide the initial impetus to an alternative energy technology industry. Within the context of the USA, in particular, this strategy makes a good deal of economic sense. American private industry is extremely well-equipped to achieve the technological breakthroughs needed to ensure the technical viability of most of the proposed alternative energy conversion systems, whether this involves reducing the unit production costs of the photovoltaic cell or developing cheap efficient storage technologies for low grade energy. The investment of time and resources necessary to achieve these breakthroughs, however, and to make them commercially viable, is likely to be considerable. The uncertainties and hence the risk associated with R & D of this type necessitates some form of government intervention; consequently, the cultivation of overseas markets is one way with which to reduce the element of perceived risks.

Private Sector

Although the extent of recent government support for private sector initiatives in alternative energy is significant, there already exists a sizeable alternative energy technology industry within the advanced countries. Recent estimates are that firms in over 50 countries are in the process of developing or manufacturing solar water heaters (Agarwal 1978). In Israel and Australia, for example, private sector firms have produced and sold these alternative energy systems for some years: Australian firms have produced solar flat plate collectors for 15 years, and have exported small numbers to Indonesia, Kenya, Singapore, Taiwan, Fiji, Barbados and Malta (ESCAP 1978). There is evidence that in the larger industrial countries some private firms who are engaged in developing or producing these technologies, are beginning to recognize the Third World as a potential market.[11] This is reflected both in their R & D efforts and in their marketing strategies.

So far, the type of technology supplied by the West for use in developing countries has been relatively simple and limited largely to the French-type solar pumps, flat plate collectors, wind-driven irrigation systems, and other simple devices such as solar cookers. The use of solar-powered systems to provide water for domestic and irrigation purposes has attracted a great deal of interest. A number of European companies, including AEG and Dornier, are working on small 20 to 500KW power plants to supply solar thermoelectric power to villages (Agarwal 1978). It is hardly surprising that the established international electric power equipment firms show such interest: the use of the sun as a power source does not require major adaptation of the existing distribution technology which they can continue to supply, as well as provide the new solar-powered turbines.

Private companies are also directing their efforts towards more complex renewable energy conversion systems with Third World markets very much in mind. The best known of these technologies is the solar photovoltaic cell which, technically speaking, may be thought of as an ideal device for rural areas in the Third World, as it requires little maintenance and is reasonably durable. An optimistic forecast is that the cost of photovoltaic cells will be reduced to $1-2/peak watt in 1980, to 50c by 1986 and finally to 10-30c by 1990, or perhaps even earlier (US Department of Energy 1978).

The private sector recognizes the potential value of solar cells because of their wide range of applications, and firms engaged in electric power equipment, oil, and chemical production have undertaken solar cell R & D on a major scale. American firms at present engaged in work on photovoltaics include IBM, Texas Instruments, Varian, RCA, Motorola, Mobil-Tyco, Dow Corning Union Carbide, as well as semi-conductor companies, and specialist firms such as Solarex (Hayes 1978).

Two firms which are actively developing photovoltaic power systems suitable for use in rural areas of the LDCs are the French firm Pompes-Guinard, and the American giant Dow Corning Corporation. Pompes-Guinard has developed a water pumping system powered by solar panels containing photovoltaic cells, which has already been installed in villages in Senegal. The firm is attempting to bring the production of all elements of the solar pump under its control. It is interesting to note that Guinard is part of the Leroy-Somer group, manufacturers of electric motors, and has just formed a joint venture with US-based Solarex to manufacture solar panels in France. To complete the circle, these solar pumps will be marketed in the developing countries by a joint venture called the Economic Interest Group, in which the state-controlled oil group Elf holds 51%, Guinard 29%, and French battery manufacturer, Wonder, the final 20% (Curry 1978).[12]

Dow Corning is extensively involved in the production of silicons and silicon-based materials for use in solar systems. Their approach to the Third World market is interesting in that they appear to stress the economic viability of solar-based electricity generating systems and encourage their local assembly in the developing countries. Relying on the example of semi-conductor production in

South Korea and Taiwan they argue that the labour-intensive nature of current fabrication practices for silicon solar cells and solar concentrators makes Third World production economically attractive (Goff and Currin 1977; Currin and Warrick 1977).[13]

It is intriguing that Dow Corning is not concentrating on solar cell electric power technology in its entirety, as is Pompes-Guinard, but on a particular set of elements within the system, including the polycrystalline silicon cells, diffusion furnace tubes, silicon gel and conformal coatings to protect the cells. Dow is also developing similar products for use in other alternative energy systems: e.g. lubricants for use on solar tracking systems, silicon resin coating to protect the surface mirrors and lenses, lubricants for alternators, transformers, etc. used in wind turbines and other exposed energy systems. Hence, Dow's willingness to encourage local production is explained by its interest in developing export markets for its raw materials as the following quotation from a publicity brochure demonstrates, 'Dow Corning, as a global organization, is looking for our proper role in this new field where we can provide the strengths of a major raw material supplier' (Dow Corning 1977).

Pompes-Guinard and Dow Corning are interesting examples because their strategies for supplying alternative energy systems to the Third World closely parallel the forms of technology transfer utilized by technology suppliers in other sectors. Pompes-Guinard may be seeking to provide its water pump as part of a 'package' that includes solar panels and piping not produced by the firm. As a result, developing countries will not be able to acquire just the pump, but will have to purchase the entire system, composed of elements that they might have been able to acquire more cheaply on the open market.

On the other hand, Dow Corning, by specializing in the supply of only one element in the solar energy system, may be attempting to establish a quasi-monopoly in parts of the Third World. Once again, the evidence is slim, but if the trend continues these forms of technology transfer may result in unnecessarily high costs to the Third World (UNCTAD 1975; Vaitsos 1974).

Biogas technology is also receiving considerable attention from the private sector. One of the better-known developments so far is an innovation in the design and construction of the conventional biogas digester. Traditional Indian designs call for a digester made of concrete with some type of covering, usually galvanized iron. A significant portion of the capital costs is allocated towards these two items. A number of firms in the UK and Taiwan, however, are currently marketing a digester made completely of neoprene plastic, with a capital cost significantly below the cost of the more traditional forms.

Less well-known perhaps is the recent development by FIAT of a high efficiency, methane-fuelled electrical generator which can be used as a source of household energy. Based on a Fiat 127 automobile engine, the generator uses methane at an alleged 90% efficiency rate and generates 15KWh of electricity as well as a great deal of heat which can be used to warm water for household use. Fiat hopes to sell 50,000 units by 1982 and is collaborating with FAO in 'examining possible applications in the Third World' (*International Herald Tribune*, 12 March 1978).[14]

The fact that a relatively small R & D effort in the West has already produced significant advances in alternative energy technologies is encouraging. There may be some technical problems in the foreseeable future, which only the West will have the technical capability to overcome. The efforts should continue and institutional means of transferring the new technologies to the developing countries should be created. As we argue below, however, there may be areas where the Third World could make *significant* technical contributions. If these are made instead by Western private sector firms, the whole range of problems already associated with the transfer of technology in the industrial sector may begin to arise in connection with transfer of alternative energy technologies.

Aid Agencies

We have already pointed out that Western aid agencies have acted as conduit for capital funds for investment in conventional electric power capacity in the LDCs. As a result, they have facilitated the flow of Western heavy equipment to those countries, accounting for a large part of their technology requirements. While most of the aid agencies are still in the early stages of formulating their programmes in the rural energy area, it seems likely that Western technology will again be a central component in their efforts.

We have shown that the French and American governments are subsidizing private sector technology exports with the explicit intention of creating markets in the developing countries. It seems logical that international agencies such as the World Bank and the

UN will also offer Western technology as part of a package of support in this area.[15] There is already some evidence of such a tendency, although it is still too early to determine if this will be a permanent characteristic of their pattern of support.

A number of aid agencies, for instance, have commissioned the Overseas Development Council, a non-profit research group based in Washington, to carry out a study on village energy use in Africa. The main objective was to make policy recommendations to African governments and to outside donor agencies on the sort of efforts that are necessary to deal with village energy supply problems. The private sector, as producer and distributor of alternative energy systems, is accorded a central role in most of the recommendations outlined in the study. As an initial starting point in a national rural energy planning effort, the ODC recommends a survey of the prospective *market* for village source energy technology.

> The purpose of this survey is to help the private sector and public energy policy makers determine what quantities of each kind of device can be sold to villagers. . . That will enable those in the private sector to decide whether such a venture is sufficiently profitable for them. . . (Howe 1977).

The ODC report correctly places a good deal of emphasis upon identifying the nature of effective demand for energy in the rural areas as part of the process by which technical solutions should be developed and supplied. This is a sound suggestion that may help to avoid the pitfalls encountered by other attempts to transplant externally developed technologies into the rural areas. The factors that govern village acceptance of new technologies are highly complex and need careful consideration before the design of an alternative energy system can be undertaken.

The assumption that aid agencies should work closely with the private sector rather than with universities or public sector R & D institutions seems misplaced, however, or at the very least somewhat premature. This is particularly the case if private sector firms are to be given the mandate to produce technologies that they deem profitable, since it is unlikely that what is privately profitable will also be socially optimal in this sector. Nevertheless, the intention of tying aid with technology is clearly set out in documents issued by the US Department of State. The National Research Council's contribution to the US statement for UNCSTD strongly emphasizes the role of the private sector in alternative energy programmes in LDCs:

> Most of the programmes we propose would be supported by the US government, although substantial contributions by US industry would be needed for several...Such developments provide expanded markets for US technology (US National Research Council 1978).

Collaboration of private firms with national and international aid efforts is not unique to the energy sector, and the problems created by tied aid have been discussed extensively. The national aid agencies must be seen to contribute to the development of markets for domestic firms; if not, aid legislation may be given a rough ride by politicians. The fact that the aid agencies attach such considerable importance to technical assistance, however, underlies a potentially harmful orientation in their approach to the rural energy problems. Although the aid agencies exhibit general recognition of the need for vastly improved data bases on rural energy use, the emphasis of their published statements and funding efforts has largely been on the need for appropriate technical solutions to the problem (Howe 1978).[16] This orientation reflects, as we have noted, both the influence of the private sector and a more general Western perception that the problems posed by renewable energy sources are largely technical and can be solved given sufficient effort.[17]

The extent to which the objectives of the aid agencies will influence those of recipient governments as regards solutions to the rural energy programme is open to question.[18] The agencies are offering assistance to Third World countries in developing their national energy plans through the provision of experts, funding of research, training programmes, etc. As a result, in the short term at least, the aid agencies will probably be a significant source of funds for Third World research in this area and consequently will have the potential to influence the orientation of that research. The technical bias of the aid agencies may influence the developing countries to concentrate their scarce resources on R & D in areas where the West already has a major lead.

IV. IMPACT ON THE DEVELOPING COUNTRIES

A central theme in the discussion so far has been that private firms in the West are devoting increasing amounts of effort and resources to the development of technologies which utilize renewable energy sources. One of the main objectives of these firms, many of which are large global corporations with sizeable Third World operations, is to market these technologies in the developing countries, particularly in rural areas, where they have already demonstrated their marketing ability (see, for instance, Langdon's case study of the impact of international corporations in Kenya; Langdon 1974).

This situation is likely to have a number of implications for any Third World attempts to develop a rural energy policy that relies on alternative energy systems. Firstly, even if they are able to generate indigenous technologies, they would still face the strong economic arguments for importation versus local development which always exist (with some justification) in these situations (Cooper and Hoffman 1978). The developing countries must take these factors into consideration when devising their technology policies.

Secondly, the location of the majority of R & D activities in this area in Western countries will probably affect the direction of technical change. Although Third World needs will be taken into account to some extent, new innovations will inevitably reflect conditions in the West rather than those in the rural areas of the Third World (Cooper 1973). Consequently, if the Third World relies on Western firms to supply alternative energy systems, access to available technologies may gradually be denied to those groups with the least influence in the market, i.e. the rural poor. This may occur either because the systems will be too expensive or because they were designed for Western conditions. If Third World governments subsidize the purchase of these energy systems, they are likely to have to pay a monopoly price. Moreover, technical options which might be very suitable to conditions in rural areas might not be pursued because, within the developed country context, they will be considered economically infeasible.

Finally, what we are witnessing within a potentially significant subsector of productive activity is the creation of the basic conditions for technological dependence over the longer term.[19]

The overwhelming amount of alternative energy R & D being carried out in the West implies that the technical knowledge necessary to tap the energy potential of the sun, wind and organic matter is being generated and concentrated primarily in the developed and not in the developing countries. More importantly, the involvement of private sector firms not only in R & D but also in design, production and marketing of the resultant technical systems (or hardware) means that they are accumulating the complex set of technological capabilities needed to exploit the commercial value of that technical knowledge. Western firms already possess these capabilities which were largely responsible for their huge technological lead over the Third World in other sectors (Junta 1976; Stewart 1977), and they are now simply proceeding to develop them in another highly specialized direction.

In the developing countries, on the other hand, in addition to extremely low levels of R & D, these technical skills are either non-existent or tend to be isolated from the productive system (Cooper 1973). The importation of Western renewable energy systems, even if they are initially subsidized by aid, will inevitably mean the substitution of foreign technological capabilities for local capabilities, thereby denying local entities the opportunity to develop their own productive capabilities (Cooper and Maxwell 1975). This will further reduce the potential for altering these dependent relationships in the future.

As we have seen, a massive inequality is being built up in the international distribution of capabilities relevant for the exploitation of alternative energy technologies. The pattern of R & D expenditures indicates that substantial research and development capabilities are being accumulated in a handful of industrialized economies, and that their scale far outweighs those being accumulated in the whole of the Third World. The emerging overwhelming strength of the industrialized economies in this area of technology is being carefully hooked into the existing structure of relationships between advanced and developing economies. Commercial enterprises and public bodies which fund the development of alternative energy technology already have their eyes on the markets of the Third World. Links are already being forged between aid agencies and the developed country suppliers of technological services relating to non-conventional energy, as are links between aid agencies and developed country suppliers of goods and systems. At the same time, joint projects between developed and developing country institutions, together with training courses organized by the former are being planned and operated. To some extent, at least, professionals from the Third World are being informed and

oriented by the directions of technological development occurring in the developed countries.

If Third World markets for non-conventional energy systems should expand significantly, private foreign investment in local production may well take place and will probably follow the same pattern as in other sectors. In short, this scenario will need little development or elaboration before it looks remarkably similar to the present costly state of affairs with respect to conventional energy technology discussed in Section I.

V. STRATEGIC POLICY RESPONSES

We have identified two major trends regarding the role of alternative energy technologies in meeting the energy requirements of rural areas in the Third World. Firstly, the growing interest and commitment among Third World governments to substantially increase the use of renewable energy sources. Secondly, the creation of a state of technological dependency between the advanced and the developing countries in the area of alternative energy technologies.

These two factors pose a formidable challenge to those concerned with formulating and implementing policies relating to the technological dimension of the growth of the rural energy sector in developing countries. In the context that we have described, what is required is not simply that individual decisions about alternative energy technology be taken on an informed basis, though this is important in the short term. These decisions must also be taken within the context of a long-term strategy which on the one hand will provide the technological inputs needed to develop appropriate energy systems, and on the other will respond effectively to the challenge of the process of dependency creation which is already evident.

Trying to implement such policies, however, will inevitably involve trade-offs in the short run which will be costly in both financial and welfare terms. Investing in the creation of local technological capabilities rather than importing foreign energy systems (i.e. capabilities) may mean that fewer rural people will have access to adequate energy supplies in the short term than might otherwise be the case. The social costs of investing in capability development will be high for a considerable period of time (Johnson 1975).

Nevertheless, it may be useful to speculate on the orientation and component elements of a long-term technological strategy in this area. Such a strategy can itself only be a component of an overall policy for rural development and needs to be tied into policies for agricultural development, employment creation and investment in social infrastructure.

There could be at least three clearly defined components to a technology policy for utilizing renewable energy in the rural areas. Firstly, and most obviously, is the need to generate the relevant information relating to energy use in rural areas and the economic and social viability of various technical options (Brookhaven 1976). This, in itself, is a major undertaking which most countries have yet to begin on a comprehensive or co-ordinated scale.

Secondly, there must be some effort to control the activities of Western firms and of the aid agencies promoting the interests of these firms. Many countries already have experience in this area, particularly in Latin America (Andean Pact 1976). One would expect it to be relatively easy to generate a set of guidelines to control their activities. How politically feasible the successful implementation of such guidelines would be is another story altogether, since there would be very powerful interest groups in opposition.

The third component is a set of policies designed to generate the technological capabilities needed to meet the needs of a long-term rural energy policy. Even at a general level, our knowledge of what interventions are necessary to create capabilities is extremely limited. Empirical evidence is fragmentary and anecdotal in the field as a whole (Katz 1978; Maxwell 1978), and practically non-existent for the non-conventional energy sector. It is quite likely that the common perception that the developing countries lack any sort of technical capabilities is misplaced, but we are still far short of being able to specify which capabilities are necessary, how much to invest in their creation, and where they should be created. Policy guidelines can only be based on further empirical work that disaggregates the set of skills that developing countries must acquire to generate an indigenous solution to their rural energy problems.

To do this, it would be necessary to specify the different categories of required skills: (a) to carry out 'market' research identifying user requirements at a technical, economic and social level; (b) to carry out R & D on renewable energy sources; (c) to modify imported systems to suit prevailing local conditions and requirements; (d) to design, fabricate and test the conversion systems; (e) to specify design and engineering parameters necessary for mass or localized production of the systems; (f) to actually produce the systems (including the provision of the necessary capital goods, raw materials, intermediate inputs and spare parts); (g) to 'market' or distribute the systems to users; (h) to maintain the existing systems (and feed back in to the production system suggestions for improvements and innovation). This list is incomplete, of course, but it gives some idea of the complexities involved in trying to disaggregate the issue of technological capability.

In addition to this disaggregation of skills, it would be necessary to assess the potential contribution of each energy source (renewable and fossil fuel) to meeting rural energy needs. Rather than total reliance on one form of energy, it is likely that energy requirements will have to be met from a variety of sources supplied by a range of technical systems that are complementary to each other.

Equally, it will not be possible to acquire conversion systems solely from domestic producers. Although technological self-reliance is now a stated objective of many developing countries, it is neither feasible nor advisable that this objective should imply total autarchy in alternative energy technology or in any other sector (Sagasti 1976; Cooper and Hoffman 1978; Bell 1979). Hence, countries may have to adopt a diverse set of strategies to acquire different capabilities and technical options according to their natural and technological resources endowments.

Industrial firms often pursue strategies to acquire technology which they deem essential to their competitive survival. In some cases, they develop it internally through R & D (through the creation or mobilization of the necessary technological skills within the firm), while in other circumstances, they acquire the technology from outside sources (Freeman 1974).

For instance, a firm or a country may decide to maintain market or international leadership in a particular capability, or in the set of capabilities required to produce and operate a particular technical system. An example from the energy sector might be where the oil-producing countries or firms must maintain an international leadership position in petroleum extracting and processing technology, but not necessarily in wind energy technology. Brazil has made a decision to achieve technical leadership in ethanol extraction from cassava and sugar cane and $500m have been invested in R & D, but not in solar technology where the allocation is only $2.5m (Powell 1978). Dow Corning's strategy is to achieve leadership in silicon lubricants, not in the entire solar cell system.

Alternatively, it may be advisable to adopt a more defensive strategy which implies that while technical leadership is not a necessity, the firm or country must remain aware of developments by the leaders in the technology and must maintain a technological capability to adopt new techniques and possibly incorporate major technical changes to suit local conditions. India's policy on solar cells probably approaches this type of strategy. There are other options such as following a purely imitative or wholly dependent strategy vis-à-vis industry or technology leaders in a specific system.

All of these strategies imply investing in various types of technical capability to different degrees according to the policy objectives of the country. Although the issues are complex, the above discussion indicates that it is possible to approach the problem of policy formulation in this area in a more constructive fashion than has previously occurred.

Obviously, there are enormous differences between industrial firms and Third World planning offices. No matter how concerted the effort of the developing countries in this field, their relative weight must remain quite small compared to such activities in the developed countries. The overwhelming bulk of technical capability lies with the advanced industrial economies, and consequently the overwhelming bulk of knowledge creation, accumulation and appropriation will take place there.

Developing countries may have to adopt more aggressive strategies vis-à-vis the acquisition of foreign technology. This may imply taking active steps to become an informed buyer of technology from the West and to maintain a careful watch on technical developments there. This in itself requires another set of evaluative capabilities, but can only ensure that the developing country will know what it is getting from the West. What it can purchase may still be highly inappropriate to its needs, as was argued earlier.

A developing country will need to adopt an equally aggressive strategy towards acquiring the technological capabilities that it deems necessary to its *short-term* objectives but which will take considerably longer to build up locally. Private firms are often faced with this situation where their plans require the use of technological capabilities they do not possess or which they cannot accumulate in time to meet its needs. A common response to this situation is for the firm to acquire an enterprise which has the necessary technological capability through takeover or merger — quite simple in capitalist economies. It may be that this type of technological activity can be built into Third World strategies.

While local capabilities are being built up, existing capabilities in the advanced countries can be acquired through acquisition. The firms can then be turned away from working on developed country problems and made to focus their capabilities on the problems of the developing country. Already appropriated knowledge can be acquired and the Third World will have control over any new knowledge techniques that the firm generates.

Such aggressive efforts to turn the technological capabilities of the advanced countries towards the problems of the Third World are likely to be far more effective than any number of international resolutions calling on the rich countries to use their scientific and technological potential to provide energy to the poor of the Third World.

• NOTES

1. The concept of technological dependency is discussed in Section IV.

2. This section is largely based on these studies.

3. Ten transnational groups dominate the international electric power equipment industry: ASEA, Brown-Boveri, AEG/Siemens, General Electric, Westinghouse, Toshiba, Hitachi, Mitsubishi, GEC and Parsons.

4. The IEA and other cartels control most exports of heavy power equipment — 75% of power generating equipment, electric power machinery and distribution equipment, and 10% of other equipment.

5. For instance, between 1965 and 1967 Venezuela purchased 79 large transformers. It paid well over the agreed minimum reference price for 60 transformers including 238% excess for one order of seven transformers. Reference prices are set by the IEA and are the minimum prices on which members can base their bids to buyers. According to the UNCTAD reports, these 'prices' do not appear to be systematically related to prices that might prevail on the international market. Available information indicates that South Korea, Kuwait, the Philippines and Indonesia have also paid these 'agreed' prices for their transformers (Newfarmer 1978; Epstein and Mirow 1977).

6. This situation has been examined in Brazil by Epstein and Mirow. By the mid-1970s Brazil had a relatively well-established electric power equipment industry

with both foreign subsidiaries and Brazilian firms supplying the majority of demand. Through a series of manoeuvres and legally questionable actions against local firms, TNCs and their subsidiaries have either taken over local firms or forced them to go bankrupt. The TNCs appear to be systematically reducing local production capacity across the whole range of heavy power equipment through their control over the production activities that remain.

One particularly effective way of eliminating competition is through the control the IEA exercises over materials and components required by independent producers. For instance, production of copper wire, an essential component for electrical equipment, is dominated by two international cartels. In 1969, cartel members purchased the equivalent of a year's supply of wire from Brazilian producers. Thereafter, the wire disappeared from the market and many independent equipment producers were either taken over by TNCs or forced out of business because they could not meet contract obligations (Epstein and Mirow 1977).

One interesting statistic in this regard is that imports of electrical equipment into Brazil increased from $74.5 million in 1964 to $533.4 million in 1974, an increase of 616% to GNP growth.

7. For instance, India has devoted most attention to the energy problems of the rural sector (see India 1965, 1974).

8. In this sense, the governments are following the classic strategy of undertaking the early, high risk period of investment in alternative energy technologies, in the hope that the private sector will come into the field after commercial viability has been demonstrated. So far the policy seems to be working. A number of Fortune 500 companies have taken up generous government subsidies and have either taken over smaller R & D-oriented companies or have set up their own. Atlantic Richfield bought Solar Technology International, Mobil acquired Tyco Laboratories and Shell is majority owner of Solar Energy Systems, while Exxon and Motorola have started their own firms. Other energy forms are also of interest to American firms. A number of large grain firms such as Holly Sugar, Archer Daniel Midland and Standard Brand are interested in producing ethanol from organic material while Boeing, Martin Marietta, Westinghouse and General Electric have lobbed (unsuccessfully) for government support of a billion dollar solar-powered satellite system (Smith 1978).

9. The firms involved are Regie Renault, auto and engine manufacturers; Commissariat à l'énergie atomique (CEA); Compagnie Français des Petro, TOTAL Petroleum Company (liquid gas transportation and storage techniques) and Anvar.

10. Recent research carried out by the International Institute for Environment and Development confirms that the French government plans to continue its programme of heavy subsidization of alternative energy technology exports to the Third World.

11. In one important dimension there may be greater potential for the export of Western alternative energy technology to the Third World than has existed for other Western technologies. This is simply because the rural populations have been identified as the target group for a private sector technology, whereas most Western technologies, however appropriate, have had a more limited market in mind.

12. The firm is basing a good deal of its planning on the expected fall in the cost of solar cell production which is being argued by the US Department of Energy (Curry 1978).

13. Dow Corning's support for local fabrication of solar cells is cause for some interesting speculation. If the current high production costs for solar cells are based significantly upon high labour costs in the developed countries, as the Dow Corning reports seem to imply, then it would be logical to suggest that production in the Third World may bring the cost down in the short term. Yet, there does not appear at the moment to be any attempt by developed country firms to locate production in the developing countries. One possible conclusion to draw from this is that the firms are attempting to restrict access to this technology by the developing countries until they can innovate to reduce labour input and remove the necessity for locating production in areas of cheap labour. This is the obvious strategy for Dow Corning and other firms who wish to protect what must be a sizeable investment in R & D. The argument has possibly important implications, however, for the Third World technology development strategies which will be taken up in the last section.

14. If one looks closer at the figures in this example, a very different story emerges. The capital cost and energy output of these units far exceeds the investment capabilities and energy requirements of the typical rural household. The capital cost is estimated to be about $3,750/unit and the engine requires six cubic meters of biogas per hour. To supply that amount of biogas per hour would require the daily output of eight family-sized biogas plants, each producing 100 cubic feet of methane per day!

15. Indeed, UNESCO is already engaged in such an effort in Senegal where, with the support of Western research institutions, it is establishing what they term Rural Energy Centres, villages with integrated energy systems based on renewable energy sources (Usmani 1978; Lawand 1976).

16. A good example of this technocratic approach is the attempt by UNESCO to set up Rural Energy Centres in a number of Third World countries. These villages are intended to be totally self-sufficient in energy by being based on a complex integrated system of wind, solar and biogas technologies. This integrated system is being engineered by Western consultants and transplanted into the village. Needless to say, there are many problems with this sort of approach that have been well-documented elsewhere (Ibidem).

17. One exception is a report issued by the IDRC of Canada, on the role of biogas technology in the Third World. The studies by Barnett and Pyle both emphasize the need to consider investment in biogas as only one option out of many open to both energy and non-energy related national governments and to the rural population, rather than simply seeing the choice as only being between different types of biogas digestor (Barnett et al. 1979).

18. This has happened before. During the late 1960s-early 1970s there was a debate over the causes of malnutrition. The aid agencies and Western private sector firms argued that lack of sufficient protein caused malnutrition. Sizeable amounts of Western aid went to Western firms to develop and market protein supplements, while many Third World governments invested heavily in R & D in this area. It was subsequently discovered, however, that an overall shortage of calories (i.e. food) due largely to low income levels among the poor was responsible for many cases of malnutrition (Joy 1973; Payne 1974).

19. Patel (1974) and others (UNCTAD 1975) have tended to have a slightly different connotation of the essence of technological dependence. Their main concern has been with the financially visible signs of this dependence.

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MICROELECTRONICS, INDUSTRY, AND THE THIRD WORLD

Kurt Hoffman and Howard Rush

As microelectronics revolutionises production in the developed countries, the traditional export successes of the Third world (eg garments and electronics) are threatened. That trade, which has grown rapidly in the past decade, relies heavily on the comparative advantage of low-wage high-skill labour. People are flexible—they can learn new skills and adapt to new fashions. But microprocessors are eroding that advantage. The newly industrialised countries, in particular, may be able to respond by competing in a wider range of exports. However, there is an urgent need for government intervention to ensure that the less developed countries acquire the software capabilities needed to make full use of the new technology.

The productive sector of the advanced industrial economies is devoting considerable resources, time, and creative talent to the commercial exploitation of microelectronics. Despite their recent emergence, microelectronics have revolutionised the ability to receive, manipulate, and transmit information. Dramatic reduction of costs and increases in reliability, have allowed the new technology to take over information-processing functions previously carried out in productive systems by mechanical, pneumatic, hydraulic, or electric devices. Examples include such varied products and processes as cash registers, television sets, machine tools, and plant-monitoring systems. That the impact of microelectronics will be widely felt in developed economies is perhaps most evident in the fact that robots and automated factories—once the dream of imaginative

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engineers and managers—have already left the drawing board for the shop floor in Japan, Europe, and the USA.

What socioeconomic consequences will accompany the widespread application of microelectronics in the developed countries? Views about the size and direction of such effects vary widely, depending partly on the country being analysed and partly on the technical background and political orientation of the research group doing the analysis. Enthusiastic optimists see new jobs emerging to replace the alienating occupations swept away by the new technology. Others offer a more pessimistic vision of mass unemployment and social crisis, particularly if new labour-displacing systems are introduced without the consent or participation of the workforce.

Whichever view proves more accurate, both are limited by ignoring the potential international ramifications of the diffusion of microelectronics. The nature of the technology, and of the changes it will bring about ensures that the effects will not be felt solely in the advanced industrial economies. Many Third-world countries strongly linked with the world economy will, we believe, also experience effects which could spread across all aspects of economic, political, technical, and social relations at both the international and the national level. This article is an initial and largely speculative attempt to discuss those effects. We have tried to bring together the existing empirical information and assess its implications. Developments in two sectors, garments and electronics, are used to highlight some of the most important issues—and we conclude the article with a review of possible responses from the less developed countries.

The existing pattern of Third-world exports

A priori, little information leads one to expect that these impacts will not be beneficial overall. There is, however, already considerable evidence that the use of microelectronics could lead to changes which may significantly alter current patterns of Third-world trade, particularly in manufactures. These changes could take a variety of forms, including shifts in comparative advantage, increased levels of protection in developed countries, or the creation of newly tradeable products or skills.

The trends in international trading patterns, and the underlying structural characteristics which determine the international distribution of benefits, set the context into which microelectronic-based innovations will be introduced. Given the heterogeneous nature of the less developed countries, the effects of the new technology will differ significantly across Third-world countries.

It is arguable that the newly industrialised countries have the economic strength and technological capacity to adapt to a rapid change and competition in the world economy. It is equally plausible, however, that for some of these countries, the nature of their integration into the world economy will prove problematic. Export-oriented economies solely dependent on cheap labour may lose their comparative advantage in a relatively short time, with potentially severe balance-of-payments and employment effects.

Developing countries which are just beginning to diversify their industrial activities, and regard exports to developed-country markets as a major engine of growth, face an additional set of obstacles. Internal economic difficulties in the developed countries, in part reinforced and in part occasioned by microelectronics, may contribute to an atmosphere profoundly biased against allowing cheap-labour imports from a growing number of poorer developing countries. Unlike the newly industrialised countries, they probably do not have the technical capacity to respond to changes in competitive conditions. The technological requirements for competing in high-income markets will be beyond the capabilities of many Third-world countries.

Any shifts in comparative advantage which result from the widespread diffusion of microelectronics in the advanced industrialised countries is bound to have repercussions inhibiting the recent Third-world efforts to increase their exports of manufactures. Although available estimates vary widely, the overall annual rate of growth for all developing countries was estimated to be around 26% for the period 1967–1974.[1] If divided by region this works out to an average rate of growth of 35% for Latin America, 34% for Africa, 20% in the Middle East, and 29% in the rest of Asia.[2] Nearly 40 of the less developed countries were able to export manufactures valued at $100 million in 1975 and roughly half exported in excess of $200 million. In total value, exports of manufactures have increased from $4·6 thousand million in 1965 to $55 thousand million in 1977, an annual growth rate of 14%.[3]

Obviously, these aggregate figures hide important differences across countries and between sectors. In reality only about 12 less developed countries (the newly industrialised countries) account for nearly 80% of total manufactured exports from the Third world.[4] For these countries the increase is a significant achievement (often obtained at a high social cost) particularly when it is balanced against some of the more pessimistic economic forecasts made during the past decade.

Developing countries traditionally enjoy their greatest comparative advantage in labour-intensive products such as garments, textiles, shoes, and leather goods. While relatively more complex and capital-intensive products are now also produced in the Third world, labour-intensive goods still account for a sizeable percentage of total exports and continue to be important sources of employment and foreign exchange. For the newly industrialising countries, labour-intensive goods account for over 40% of manufactured exports from South Korea, Taiwan, Hong Kong, and Singapore, and over 20% from Brazil, Argentina, and Mexico. For the less industrialised countries, the percentages are even more dramatic, accounting for 73% of manufacturing exports in Egypt, 79% in Pakistan, 52% in India, 97% in Bangladesh, 71% in Iran, and 61% in Morocco.[5]

From the mid 1960s to the mid 1970s the rate of growth of these exports has been phenomenal. For garments and textiles, the annual growth rates between 1970 and 1975 were 20·3% and 17·8% respectively.[6] These impressive rates of growth in the export of traditional manufactures have led many less developed countries to formulate medium-range to long-range industrialisation plans which rely on continued increases in their exports of these products. South Korea has announced plans to double the size of its textile industry by 1985.[7] China, Taiwan, India, and Singapore have all recently presented planned increases of similar magnitudes in textiles, garment, and shoe production.

The recent growth figures, however impressive, must also be seen in the perspective of total world trade. For example, the less developed countries' share of developed-country markets for garments and textiles was still relatively small up to 1975: they accounted for 4% of the domestic market in the USA, 8% in West Germany, 6% in the UK, 5% in Canada, 4% in Japan, and 2% in France.[8] The core of the problem faced by the developed countries is that the size of penetration for these product groups relative to total imports has been high. For instance, recent estimates show that imports of garments from the newly industrialised countries account for nearly 75% of all less-developed-country-manufactured exports into the UK: imports from newly industrialised countries account for 57·5% of all UK garment imports which in turn meets 30% of home demand.[9] For the OECD as a whole, in 1977, 38·5% of all clothing imports (Standard International Trade Classification 89) originated from newly industrialised countries, 31·3% of all leather goods imports (SITC 61, SITC 83.05), and 10·8% of all textile imports (SITC 65): other less developed countries accounted for an additional 5% of clothing, 2·5% of leather goods, and 5·3% of textiles.[10] Such product-specific penetration in developed-country garment and textile markets is the prime cause of increasing protectionist pressures which conflict with the conventional free-trade policies espoused, at least publicly, by developed-country governments.

The expectation that exports of labour-intensive products can continue indefinitely to grow rapidly is unrealistic given present conditions in the developed-country economies. Most recent forecasts by international agencies such as the World Bank suggest that exports will continue to grow through the 1980s. According to these reports, the growth rates will be much lower than in the previous decade, with garment exports increasing by only 5·5% per year and textiles by 4·3%.[11] With the potential diffusion of new microelectronic-based technologies, however, even these estimates must be reexamined.

Particularly susceptible are production systems in those sectors where the less developed countries enjoy a comparative advantage based on cheap labour–sectors which account for the largest (garments, textiles, shoes) and most rapidly increasing (electronics) shares of exports. The production process in such sectors is characterised by a number of discrete stages. These can be entirely labour intensive (as with garments and shoes) or partly labour intensive (as with the assembly of electronic components and final consumer products). The introduction of microelectronics may lead to improvements in overall productivity great enough to overcome the powerful economic logic of international wage differentials—the factor which gave the Third world its traditional comparative advantage and, in some sectors, tended to slow the process of innovation.

A brief description of some innovations now being developed in the garments and electronics sectors of advanced industrial countries may help to illuminate the nature of the technical changes we have been discussing.

High skill and low wages in garment production

The garment sector is a good example and provides analogies with current technical changes in similar sectors such as textiles, shoes, and leather goods.

Production is sequential—the pattern is marked, the cloth is cut, the different components of a single garment are bundled together, and finally assembled. At every stage, an operative is needed at the interface between material and machine to process the relevant information, carry out the operation manually or instruct the machine, and then ensure that the material passes to the next stage.

In the clothing industry, the nature of the information flows and the corresponding transformation activities (marking, cutting, assembling) are fairly complex. Truly repetitive activities (ie straight cuts or seams) which can be repeated on every garment are relatively rare. The wide variety in size, volume, and location of subcomponents, even within one style or production run, necessitates frequent changes in operating parameters. These are compounded by regular changes of fashion, which often require the production of a completely different type of garment. For many activities in the clothing industry, highly skilled manual operatives have proved the most efficient choice, primarily because of their ability to respond flexibly to changes in operating parameters.

Low wages and a highly skilled labour force gave Third-world firms their comparative advantage in particular subsectors. Large international firms have also moved quickly to exploit these factor cost advantages. They have located all or part of their process in low-wage countries (in locally owned subsidiaries or joint ventures) or have subcontracted out assembly activities to locally owned firms.

Automatic tailors

In the 1960s the advent of electronics speeded innovation, mainly in very specific subprocesses and with little effect on Third-world export opportunities. The high capital cost of mechanisation within those subsectors continued to preserve the comparative advantage of less developed countries. However, the widespread introduction of microelectronics is likely to lead to major changes in the relative factor costs. The new technology has the information-processing capacity and the inherent flexibility to allow radical technical changes at the subprocess and systems level by overcoming technical and economic obstacles.

The nature of such changes is illustrated by microelectronic-based technical developments which have already been introduced. The value of the cloth commonly accounts for about 50% of the total cost of the garment. The crucial phase of laying out patterns on the cloth must therefore minimise wastage. Traditionally, this has been a skilled and relatively time-consuming manual task: it includes cutting and grading the patterns, stretching the cloth, inspecting the cloth for faults, laying out the pattern, marking on the top layer of cloth, removing the pattern, and again inspecting for faults. The cutting stage is equally skill and time intensive to avoid high cloth wastage through inaccurate cuts.

Laying out and cutting have traditionally been separate tasks and innovations have occurred on the machinery used at each stage. Technology, however, is now available that combines computerised optimal-pattern layout with electronically controlled laser cutting or with high-pressure water jets. Optimal-pattern placement is automatically worked out (without laying out) and the cloth is directly transferred onto cutting machines. This has greatly reduced the time involved in these phases of the process from about one hour to under four minutes per new pattern. Skilled-labour input is reduced dramatically—one UK manufacturer was able to cut this component of its workforce from 200 to 20 skilled operatives. Savings on cloth wastage using computierised layout have been estimated at 8–15%.[12]

Technical changes of similar magnitude have also occurred in equipment used at the assembly stage: the sewing together of the separate pieces of the garment itself and such subcomponents as buttons, pockets, collars, and other extras dictated by fashion. This stage of the production process is often subcontracted out by developed-country firms to low-wage companies in less developed countries. The assembled garments, almost but not quite complete, are then reimported under off-shore tariff provisions.

The technical problems of mechanising and automating remain formidable. However, automation of sewing equipment is advancing extraordinarily rapidly. Microelectronics has facilitated the development of photoelectric edge-sensing equipment which monitors the edge of the materials to be sewn and draws the sewing heads along with it. Robotic sewing-machine heads can now be computer programmed and controlled to perform the infinite variety of stitches that are required—and they never forget how and never drop a stitch. Automatic fabric manipulators control the movement of the material and ensure that it is in the correct position to be sewn. The new technology has also led to the development of a variety of heat-based fusing techniques which replace conventional sewing of collars, cuffs, and even long seams. And continuous changes in operating parameters can now be programmed into machine heads—previously the specific process would have had to be halted while the appropriate changes were made manually.

Although fully automated garment production is not yet an economic reality, the trends in technical change and the expectations in the industry point unmistakably towards the development of increasingly comprehensive systems. The information flows for the entire process of design, layout, monitoring for faults, cutting, and sewing can now be integrated into a centralised control system. The engineering of fully integrated systems remains an obstacle but many of the interface problems have already been solved.

The impact on the Third world

Whether or not these systems affect Third-world production will depend on many factors—the price of the capital equipment and its availability, the skill required to use the new equipment, and the speed of the response by Third-world producers.

The firms in less developed countries have in the past had access to advanced equipment on the international machinery market, although to date they have tended to rely extensively on conventional multipurpose machines and cheap labour to perform manually the tasks which are becoming increasingly automated in developed countries. This combination has given them the capacity to mass produce standardised products at low prices as well as the ability to respond quickly to changes in fashion and competition. Undoubtedly these characteristics will allow Third-world producers to resist the effects of technical change in the developed countries for some time to come. But this ability to resist must gradually be eroded by the combined effects of rising domestic wages, higher and broader tariff barriers, and innovations, controlled by the developed countries, increasingly directed at activities where the less developed countries now enjoy a comparative advantage. The crucial variables are likely to be the rate at which these applications are developed and their speed of diffusion among developed countries—issues on which little information is yet available.

Offshore assembly in the electronics sector

Similar trends in technical change can also be observed in electronics. Such products follow closely behind textiles and garments as the third major group of manufactured exports from the less developed to the developed countries. Indeed, Third-world exports of electronics products have grown faster than any other product group during the 1970s.[13] The degree of penetration that has been achieved by particular electronics products in developed-country markets varies extensively but can be quite high. In 1974, newly industrialised countries accounted for 11·9% of OECD imports of electrical machinery (SITC 72). However, at the four-digit (ie specific product) SITC level, "the share varies from less than 1% for electromedical radiological apparatus and electromechanical hand tools to 29·3% for electronic components and radio receivers. On a seven-digit (SITC) basis calculated for US imports, three product groups in electrical machinery had developing-country shares above 80%".[14] This is an impressive performance in what is ostensibly a high-technology industry. It has led many less developed countries to increase their efforts in promoting domestic production activities in this sector. Unfortunately, these aggregate figures are again misleading and tend to hide structural characteristics which are not as favourable to the host countries as might at first appear.

One of the most important factors which underlie the 'apparent' success of electronics exports from less developed countries is the extent to which these exports are under foreign control. In general, the degree of foreign control varies significantly between countries and subsectors. The problems posed by an extensive foreign presence in less developed countries production have been widely discussed in the literature.[15] Although there is insufficient evidence to point conclusively to a correlation between the activities of transnational corporations and export-oriented sectors,[16] the data available do indicate that transnational corporation participation is relatively high in those sectors that have recently experienced the highest rates of export growth. Most notable among these is, in fact, the electronics sector where the combined value of exports by wholly owned subsidiaries and joint ventures was equal to 70% of total electronics exports from South Korea in 1975, 99% from Singapore in 1975, and over 90% from Argentina in 1979.[17]

The objectives of the foreign firms which dominate Third-world electronics exports are directly related to the so-called 'offshore assembly' provisions in the tariff laws of many developed countries. The best examples relate to items

806.30 and 807.00 of the US tariff schedules. Under these provisions, import duties are imposed only upon foreign value-added, when domestic materials are sent abroad for further processing and then reimported. This encourages the importation of semifinished products/components (rather than finished products) by increasing the profitability of retaining part of the production process overseas.[18] A vast range of products is imported under these provisions: most prominent are metal products (the category which includes electronics), textiles and garments, and chemicals. Minian's work in this area has shown that imports under these clauses have grown faster than the rate of growth of total US manufactured products and, more importantly, that imports from less developed countries have grown from 6·4% of this total in 1966 to 43·3% of the total in 1974—an annual growth rate of 57·4%.[19]

In garments, after supplying cut material for sewing to subsidiaries and subcontractors in less developed countries, US firms then reimport the nearly finished product. The share of these imports (under sections 806.30 and 807.00) increased from 0·3% of total garment imports in 1965 to 10·25% in 1974.[19]

The import of electronics has shown equally impressive rates of growth, increasing from 10% of all imports (under 806.30 and 807.00) in 1965 to 26% in 1974. As with garments, only very specific phases of the production process are located in less developed countries—associated primarily with assembly (which includes detailed bonding work as well as more straightforward component assembly) and testing. Within this group, imports of semiconductors and other components have grown very rapidly—both as a percentage of total imports under these clauses (from 3·3% in 1966 to 13% in 1977) and as a percentage of total US imports of these products. Parthasarthi has shown that for the USA in 1969, within their respective product categories, semiconductors and parts accounted for 96% (and was the largest in value terms) and television receivers and parts took up over 75% of total imports.[18] The total value of US imports of these products had grown dramatically from the 1969 figure of $49·8 million to $961·3 million in 1974.

This dominance of the import of assembled electronics components in the US market is mirrored at the world level. In 1973, imports of semiconductor devices accounted for 40% of electronics imports from less developed countries to all developed countries—in value terms, double the 1972 figure.[20] Under offshore assembly provisions, imports from less developed countries have shown similar rates of growth in West Germany and the Netherlands: for the period 1966–1972, the annual import growth rates were 36% and 39% respectively.[21]

Despite these structural problems, the scale of trade has probably given the less developed countries significant benefits in employment and foreign exchange. However, microelectronics-based innovations, which would allow the automation of the entire process, already threaten these largely labour-intensive activities in the assembly and testing of electronics components and final products. The strength of foreign control over such activities gives the less developed countries little recourse when decisions are taken to shift part, or all, of their production back to fully automated plants in Europe or North America. The technology that will allow this to be done is already being developed and, in some cases, introduced in production. The fierce competition in the electronics sector as prices rapidly decrease makes the relocation and automation of production an important option open to international firms.

Will automation be allowed to reach the Third world?

An example can be found in the technical developments taking place in the assembly of final products, eg television sets, radios, and home entertainment centres. Microelectronics have led to dramatic product changes. The most important has been the reduction of the number of components—it has dropped from 1200 to 400 in a (standard) television set.[22] This, in turn, has facilitated the development of automatic insertion equipment which has the potential to perform assembly activities now performed manually.[23]

Some, but relatively little, automatic insertion is already being carried out by developed-country firms. There are great differences in the extent to which the various competing firms use automatic insertion: there are variations, too, in the amount of R and D now committed towards achieving full automation. Japanese firms are the most advanced in both areas, reflecting their emphasis on the competitive strategy of reliability, efficiency, and quality. All Japanese firms producing televisions use automatic insertion for component assembly—a total of over 75% of components are automatically inserted on printed circuit boards. They also use automated testing. US and European firms lag behind in the use, and development, of automatic insertion for consumer electronics: they appear content for the moment to continue to assemble manually in low-wage countries.[22] However, automatic insertion is expected to become a major determinant of international competitiveness: given the industry's previous rapid adoption of innovations, it should not take long to diffuse amongst developed-country firms.

There is little evidence to suggest that transnational corporations will be willing to supply subsidiaries with this advanced equipment. At present, most transnationals producing televisions prefer to exploit the Third-world advantage of cheap semiskilled labour, which requires little technical back-up. Japan is the only exception, because it faces developed-country tariff and quota barriers that other producers do not have to overcome. Japanese firms have therefore located production in low-wage countries (eg South Korea and Hong Kong) and exported to developed-country markets from there. Such firms have transferred automatic insertion to some Third-world subsidiaries but will increasingly locate new production ventures, using automated techniques, in developed countries.

A range of Third-world responses

In both the garments and the electronics sectors, the responses available to Third-world firms will influence the outcome of technical change.

Countries with a capability in a specific subsector of electronics may have the inputs and expertise to incorporate electronics into industrial processes and other exports. For example, South Korea is a highly successful exporter of ships of all types. Ocean-going vessels incorporate a significant amount of electronics equipment, which South Korea has previously been able to supply indigenously. New generations of maritime navigational and communication equipment will probably incorporate microelectronics—and some observers expect that South Korea will be able to successfully utilise this equipment in its vessel production.[13] Similar examples exist in the same sector for Mexican exports of fishing trawlers, Argentinian production of numerically controlled machine tools incorporating imported electronics, and Indian and South Korean exports of textile machinery, which increasingly includes microelectronics.

This type of option is open to some, but not many, developing countries. The successful export of manufactures has, of course, been accompanied by other developments which are indicative of increasing Third-world technological sophistication and widen the range of responses available. In addition to final products and capital goods, some countries are competing internationally in a range of technology-based exports. These include both disembodied and embodied technology, supplied through turnkey projects, direct investment and joint ventures, licensing agreements, and consultancy activities. They are also increasingly engaged in the provision of civil construction services and other technical services in health, agriculture, tourism, and finance.[14] For these countries—often within the category of newly industrialised—microelectronics presents a new range of problems and policy options. Much depends upon the availability and flexibility of existing skills as well as the constraints on acquiring new skills and new technologies.

Software skills: the key to success

In the long term the key factor, both in the responses open to any particular Third-world country and in the resulting impact of microelectronics, will probably be the ability of that country to make creative use of the software element of the technology. This is because, before the microprocessor can function, it must be programmed. Instructions on how it is to process (control, monitor, or diagnose) the information passing through it must be programmed into the surface of the silicon chip. Each program can be designed to meet the precise specifications of the job at hand, be it a single start–stop instruction or the control and monitoring of all processes in a chemical plant.

As the use of microelectronics increases, demand for software services will increase. At present, the manufacturers of microelectronic products are also the suppliers of software or development aids for software fabrication. If microelectronics are being used on a large scale (eg incorporated in final consumer products) then mass standardised automatic programming is used. Alternatively, a microprocessor can be programmed to the user's exact specifications for a very particular function. Semiconductor manufacturers appear to be keeping up with most of the current demand for software services from user firms and software houses. As demand increases both quantitatively and qualitatively (for more specialised programmes) the software capacities of manufacturers and specialists will probably be outstripped at least in the short run. This results from an important differentiation between software skills: the 'know how' of programming itself and the 'know what' required to use programming skills for specific applications.

At present, software specialists meet the spillover demand (not met by manufacturers) for programming services arising from the use of microelectronics.

As with earlier generations of firms specialising in computer software packages. they still tend to be closely allied to the needs of firms in the service sector or to the requirements of administrative functions in the manufacturing sectors. However, this can be expected to change as demand increases among users in other sectors where there are fewer software skills and technically more difficult interface problems. Software suppliers will probably expand their activities to meet these wider needs—they may even specialise in the software requirements of particular sectors. Such a pattern of specialisation can, of course, already be found in many sectors. For example, engineering firms in the developed countries specialise at the sector and subsector level and are themselves playing an increasingly important role in the processes of technical change and technology transfer.[24]

The importance of software and the emergence of specialist suppliers will affect Third-world efforts to acquire production systems incorporating the microprocessor. In one sense it suggests that such specialisation is feasible for certain less developed countries. It will depend, of course, on the nature of existing programming skills and on the ability of Third-world firms to attract and keep skilled personnel, given a worldwide shortage. If it can be done, and if such a firm can specialise in software packages appropriate for use by other less developed countries, there may be a comparative advantage because of the relative cheapness of skilled labour. Some countries, eg India, Argentina, South Korea, and Mexico, are already competing effectively at the international level for engineering contracts on the basis of their cheap but highly skilled engineers.[25]

The evidence, and the emphasis, in developed-country literature suggests that a software capability, once developed, will become the linchpin around which developing countries can build their ability to fully participate in the microelectronic revolution, if and when the need arises. The extent to which such a capability depends on a detailed knowledge of how to produce microelectronic components remains to be seen, but we doubt that it will be crucial. The problem may be more one of attracting the initial foreign expertise needed to assist in laying the groundwork and doing the planning for a programme of capability development. There is currently a worldwide shortage of individuals with experience of, and exposure to, the industrial use of microelectronics. This is compounded by a lack of information on the best and most cost-effective way that less developed countries could develop software capability.

The need for government intervention

In the developed economies, the pressure of market forces appears to have led to increased software specialisation. Undoubtedly, this may lead to efficiency improvements and cost reductions within the advanced industrial countries. However, it is not at all clear that reliance on the market will be sufficient to bring forth software capability in the developing countries. The market appears to consistently undervalue the accumulation of local capabilities, because of the likelihood of high private costs of this course of action.[26] Local firms—whether foreign or indigenously controlled—will perceive these high costs and will probably rely on foreign software skills, even if suitable local skills are available. Government intervention in the local market, probably on an extensive and prolonged scale, will therefore be necessary to foster the development of a software capability which is well integrated with the productive system.[27]

Neither can it be assumed that the market will operate optimally at the international level if less developed countries are forced to acquire their software inputs from suppliers in the developed economies. This, or course, is extremely likely, since the lack of technical skills will present most Third-world user firms from meeting their own software needs. For a number of obvious reasons this will place the user in a highly disadvantageous position in the software market *vis-à-vis* specialised software suppliers. Suppliers will be able to exploit the quasimonopoly through a number of well-recognised channels such as monopolistic pricing and packaging.

Consequently, the governments of developing countries will probably need to intervene in the international market, to maximise benefits from the transaction. The objective of such intervention must be not only to minimise the element of monopoly rent but also to ensure that the transfer itself contributes to the development of local skills. It is not sufficient merely to obtain the right sort of software package at a competitive price—this sort of transfer does little to provide the recipients with the technical knowledge necessary to go on and produce further software. The emphasis must be placed on the full participation of locals in the transfer, even if they acquire only a little software capability.

The viability of accumulating capabilities around the software components, or indeed, of any other strategy, can only be properly evaluated if the appropriate type and level of information is available. Major information-generating exercises are required to ensure that policy makers in the less developed countries have access to data on a variety of categories of information, eg the nature of technical changes occurring in developed-country firms, the types of technical capability involved in using and producing innovations using microelectronics, the orders of magnitude of the potential employment, and trade effects of shifts in comparative advantage.

Given the complexity and immediacy of many of the problems facing the Third world, it is perhaps no surprise that there has been no mad rush towards research on the effects of microelectronics—particularly when much better-informed groups in the advanced industrial economies cannot even agree on the rate and direction of changes to come. However, the magnitude of the potential changes and the likelihood of their negative impact on the Third world suggest that action is necessary. Discussion and analysis, similar to work done on the developed countries, should be undertaken throughout the Third world and in the relevant national and international agencies in the advanced economies.

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Geochemistry and petrology—used with a HP-2000 minicomputer.

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Truck, frontend loader haulage in surface mining—used with a DEC 11 minicomputer.

US Geological Survey
Denver Federal Center
Building 25
Denver, CO 80225
Predicts mineral occurrences, rock analysis storage system, seismic refraction interpretation, map digitizing—used with DEC 8, 10, and 11.

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Selection Considerations—Using a Consultant

Alfred Weiss

Selecting a minicomputer is not unlike selecting a costly piece of mining equipment such as a truck, shovel, crusher, or conveyor belt system. A marked difference might lie in the frequency at which such selection takes place; another difference might be mine management's familiarity with mining equipment vis a vis a minicomputer. These basic differences might prompt a mining company to seek the aid of a consultant when selecting a minicomputer system.

Advantages and Disadvantages

The fundamental advantage of employing an independent consultant is that it provides management with a source of knowledge and breadth of experience not readily available within the organization. If the consultant has a minerals background, such knowledge and experience are further enhanced by actual experience in exploration, mining, and mineral processing. If the consultant has worked within a mining company, such hands-on experience is supplemented with a meaningful understanding of the client's business; this facilitates communication between the consultant and members of the client organization. The consultant has been, so to speak, "in the client's shoes."

There are several other advantages. Since computer systems cut across organizational boundaries, the independent consultant may be able to move within the organization more easily than an inside staff person to collect necessary information. Also, detachment from any manufacturer should provide the client with an objectivity and a set of recommendations as near optimal as feasible.

The principal disadvantages lie in the area of continuity and accountability. Once the consultant's report has been submitted and his recommendations implemented, a discontinuity might occur. Also, if implementation does not provide the desired results, the consultant might not be available to correct the situation or account for actions taken. Proper selection of consultant services, relative to kind and duration, and the consultant's method of operation, will often prevent many of these aftereffects.

Services Offered

The professional consultant can help a client:

- Define and summarize information systems technology* needs;
- Evaluate alternatives such as in-house capability and capacity, time-sharing, or service bureaus;
- Prepare a formal request for proposal (RFP) to be submitted to vendors;
- Evaluate vendor proposals;
- Evaluate the economics of lease vs. purchase; and
- Assist in the conversion and installation.

Thus, consulting services may range from evaluating an existing system and upgrading to a larger piece of equipment, to selecting a new first-for-the-organization computer.

First, Define and Summarize Needs

Regardless of circumstances, the most valuable document required before equipment selection is the information system plan (I/S plan). It helps insure that the company's information needs are met in a cost-effective manner. An I/S plan is usually a component of the mining company's overall business goals. Since an I/S plan is a formal vehicle for establishing and communicating the direction the organization intends to take to satisfy information requirements needed to achieve goals and objectives, most initial systems services are likely to center around creating such a document or updating an existing document.

The trend toward company-wide I/S planning is increasing in the mining industry; however, smaller scale efforts focused at the information systems needs to support an individual

* Information systems technology connotes computers, telecommunications, software, etc., as related to all functions of a mining enterprise including those involving process control.

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operating division or department are not always adequately covered by such a plan. The rapidly growing use of stand-alone minicomputers at the operating division level might be indicative of local, site-specific requirements not adequately met by a centrally-located mainframe.

Thus, services offered by consultants in selecting a minicomputer often consist of deriving a set of specifications from an individual operating divisional I/S plan.

Evaluate Implementation Alternatives

Once data processing needs have been defined and summarized, alternatives for implementing the plan must be considered. These alternatives must be analyzed in terms of cost vs. benefit, and should include the following considerations before a decision to purchase a minicomputer is made:

- Expanding in-house capability and capacity;
- Time sharing in-house vs. outside time sharing vendors; and
- Accomplishing the work load by service bureaus.

These considerations could prevent duplication or excess capacity. Minicomputers are an intensely competitive market, and are being squeezed by ever more powerful microprocessors. As a result, minis are aggressively expanding upward into the medium-sized mainframe realm. Acquiring a minicomputer must then be carefully assessed in light of current capacity and downstream commitments, including software expenses or conversions.

Preparing the RFP

Once the decision is made to acquire a minicomputer, the consultant may assist in preparing the RFP and subsequently evaluating the proposals. In fact, this may be one of the most critical steps in the selection process and where certain elements of the I/S plan must come into play. Defining the system with the accompanying set of specifications (Table 1) will facilitate preparation of the purchase contract, after the vendor has been selected.

In addition to describing the deliverables—both hardware and software—certain standards should be established, as well as a method for determining if each delivered item meets these standards. Criteria for evaluating not only the proposals but also the computer system should be decided upon to insure that specifications are met and that their fulfillment can be determined objectively and unequivocally. The exercise of judgment or discretion should not be necessary to determine acceptability.

For instance, some procurement practices require actual performance of installed systems, on site, according to the manufacturer's technical specifications. Effectiveness levels should be at least 90% for 30 consecutive days and involve at least 100 hours of production time.

Thus, preparing specifications and acceptance test routines for minicomputer systems or software can be laborious, expensive, and time consuming. Nevertheless, these critical elements are well worth considerable effort, including the advice and involvement of an experienced consultant.

Assistance in Implementation

In the minerals industry, minis are often installed for process control; there the computer functions on-line with a metallurgical process. Needless to say, when a computer system becomes a key part of the client's operations, and he must make lengthy and elaborate preparations for its introduction, normal remedies for delivery default are not likely to provide adequate protection.

Once contract performance has been underway for a significant period of time, the client usually cannot attempt reprocurement elsewhere because of long lead times. This is especially true when default is not discovered until the delivery date has arrived. The receipt of money damages rarely compensates for the expense and inconvenience suffered, many aspects of which are not measurable in dollars.

The consultant may help establish meaningful concrete performance milestones throughout the implementation period; including production of the computer system. This enables the client to spot key delivery failures (or potential failures) early, before his bargaining power is weakened. He can also take advantage of actual or anticipatory contract breaches, depending on how the contract is written. Designing and implementing those milestones are very important items in the implementation stage, including the contract negotiations with and execution by the manufacturer. These milestones, for instance, must include receiving confirmations of delivery dates for major items procured outside, successfully passing in-process tests of critical elements, or completing key design steps.

Operational warranties are probably even more important for minicomputer systems than for many other equipment items. Failures of computer electronic components during the initial startup period are more common than for mechanical parts. More significantly, many software packages require considerable modification and refinement because of the great difficulty in designing and debugging complicated programs. So it is essential to secure proper warranties on a system and to specify that they remain in effect for a suitable length of time.

Level of Expertise

Continuity and accountability require that the client organization name an individual within the company to act as a project leader. Depending on the level of effort, a project team or task force is usually the most effective means for giving broad participation as well as support for the I/S requirements study. Each team member should represent a major organizational component. All team members should be selected for their broad perspective and understanding of the business. They do not have to have a detailed knowledge of computers or data processing. The consultant must provide this know-how to the team.

The project leader is the key to insuring that the study progresses on schedule and accomplishes its objectives. He is usually selected from one of the major organizational components included in the study. In addition, he must possess the skill required to effectively communicate the progress and the recommendations of the team to top management. Some companies may wish the consultant to play this role, and under certain circumstances this has worked; but it usually is not recommended.

Developing an overall understanding of the business environment and defining the information required to

Table 1—Sample Items to be Considered for Inclusion in Request for Proposal

• Description of all goods and services to be furnished	• Place of delivery
• Specifications of those goods and services	• Price, including discounts
• Acceptance tests	• Terms of payment
• Time of delivery and schedule of implementation	• Warranties
• Actions to be performed by client	• Protection against patent and copyright
• Penalties of unexcused delays and other defaults	• Limitations of supplier's liability
	• Options
	• Duration of agreement

...the business are the principal activities for the consultant and the project team. If the project team includes members who thoroughly understand the functions of their respective organizational components, understanding the business environment is facilitated. It is important that the consultant and team members share a common understanding of business goals, objectives, organizational structure, and functions. A series of orientation briefings for the project team can accomplish this.

The expertise of the project team will change as the project approaches the RFP, evaluation, contract negotiation, and execution stages. More specifically, in these stages a team should include, as a minimum, a financial representative, a purchasing agent, a computer systems specialist/consultant, and a contracting or legal expert. Each specialist should be qualified to deal with the unique subject of computers. For example, the legal specialist should appreciate, at the very least, the significance of these facts:

- Systems, not merely machines, are involved;
- Acceptance tests should include objective criteria that readily and adequately reveal acceptability;
- Computer use usually makes management substantially more dependent on the continued operation of the system than does practically any other form of mechanization.

A consultant can help management select a qualified team and advise management when to change the makeup of the team.

Evaluating the Process

Perhaps the most valuable role a consultant can play is to insure senior management involvement and attention to activities of the project team. Attention must be focused on specific goals and steps toward these goals. As a minimum, the consultant must insure that management is provided with a total project timetable—from definition of needs to RFP preparation, acquisition, and implementation—and a budget. It should include steps listed in Table 2.

Since the financial aspects of the acquisition process should also be reviewed periodically, a budget should be established at the outset—and revised periodically as new data become available—to reflect both the cost of the acquisition activity and the cost of utilizing the system.

Cost and Time Involved

Various methods are used to compensate the consultant for his services. Most consultants have establishing procedures which are sufficiently flexible to adjust to the special circumstances of any particular project, depending on type and length of services required. The following are common methods:

- **Per Diem**—Computer consultant fees in the US now range between \$500-\$900 per day. They apply to intermittent or occasional services. The rate will depend on the type and location of the work as well as the experience and qualifications of the consultant. A senior consultant advising senior management on minicomputer acquisition and installation for process control purposes might charge a fee as high as \$700-\$900 per day.
- **Fixed Fee**—In cases where the scope of the work can be clearly defined and the time requirement and incidental costs accurately estimated, a single fixed amount may be charged. For instance, consulting fees to obtain an I/S plan for a medium-size mining division have required a total elapsed time of up to six months with approximately 30 man days of consulting time spent with the project team. Average consulting fixed fees range between \$20,000-\$30,000.
- **Retainer**—In cases where the

Table 2—Representative Items to be Considered for a Timetable

- [illegible] IS plan
- Preparation of specifications for the system to be used
- Selection of type of procurement transaction to be used
- Receipt of proposals from potential suppliers
- Choice of supplier for negotiations
- Drafting, approval, signing of agreement
- Adoption of acceptance test procedures
- Activities in connection with delivery:
  - —Availability of hardware for advance programming
  - —Training in programming operation and maintenance
  - —Delivery of hardware and software
  - —Start end of acceptance test
- Start of operation of computer system
- End of parallel operation of system or procedure being replaced
- Evaluation of cost of procurement effort

consulting services for planning, acquisition, and installation of minicomputer systems are required on an intermittent or part-time basis over a long period (one year or more), or when a client wishes to have such services available for immediate call, it is common practice to charge a fixed amount as a retainer on a monthly or other regular basis. The retainer may be considered minimum compensation for work up to a specified amount, with additional time to be charged at agreed-upon rates.

Conclusion

A mine manager does not select mining equipment without a mine plan—and he should not acquire a minicomputer without an information system plan. Selecting and acquiring a computer system should not be delegated to subordinate financial, procurement, and engineering personnel, without senior managers exercising control over the acquisition process. Yet the record indicates that there have been serious, inexcusable failures to use normal business practices when acquiring computer systems—especially minicomputers.

These machines are increasingly attractive as stand-alone computers at the mine operating level and in some instances are a key part of operations. Remote operations and infrequent need may not require in-house computer expertise. In these instances an independent, experienced consultant can aid senior management in defining an operating division's information system needs, evaluating alternatives to meet them, and, if required, help prepare for acquisition and implementation of a minicomputer system. □

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Selecting a Minicomputer From a Manufacturer

David Van Cleave and David L. Rome

Whether you buy your minicomputer from a manufacturer or another vendor, the first thing you must do is define your needs. With good planning, the initial cost will be low and your return on investment will be maximized over the long term. Involving all members of your staff who will be using the new computer in the planning phase is also important. Their participation will alleviate any potential concerns they may have about new equipment, and their suggestions will provide valuable input for your specifications. After you define your proposed system, survey available hardware and software. The survey will help you in the next step, preparation of specifications. The specifications, along with a quote request, are then sent to various manufacturers.

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Consider the Manufacturer

When selecting your minicomputer, one important item to consider is the manufacturer. Remember, when you buy a computer, you're also buying the services of a computer company. A firm that makes a commitment to its customers and provides a product that is field tested before releasing it for sale is preferable. Examine the company's maintenance and support packages, since every machine requires preventive maintenance. Does your manufacturer or original equipment manufacturer (OEM) support service sites in your area? Has their service record been commendable? Will they provide training for your personnel and a supply of circuit boards so you can retain a degree of self-service autonomy? Three methods of buying a computer involve the manufacturer, an OEM, and the systems house.

Buying direct from the manufacturer means you go straight to the source, using no middleman. This gives you maximum flexibility; you can consider every alternative and many possible combinations of computers, peripherals, and software until you find exactly the right system for you.

The OEM buys computers direct from the manufacturer and builds them into his own computerized, special purpose product. He usually sells a complete package, including software and hardware, and often noncompetitive equipment as well (a scientific or engineering instrument, for example), designed for the mining market. Because he offers a packaged product, the OEM can often charge less for the system than if you put the pieces together yourself. In many ways, the OEM also provides a unique system. And while the OEM sells a packaged solution, he also usually has the special market knowledge necessary to modify the system to meet your [illegible] needs, if necessary.

BIOTECHNOLOGY, SEEDS, AND THE RESTRUCTURING OF AGRICULTURE

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Introduction

The economic boom which the United States and other capitalist nations enjoyed following World War II was realized in agriculture as well as in industry. The deployment of new technologies in machinery, chemical inputs and plant breeding resulted in burgeoning productivity, relative prosperity on the farm, and unprecedented opportunities for capital to realize profit in agriculture. The development of new forces of production compelled a reformulation of social relations as well. In the last 35 years the United States has seen the virtual elimination of the sharecropper, massive concentration of farms, the rise to prominence of transnational agribusiness, and the wholesale state intervention. More recently, some of the least developed countries (LDCs) have undergone a "Green Revolution" as new technologies brought the periphery more fully into capitalist market relations.

But as capitalism entered the deepening crisis of the 1970s and 1980s, so did agriculture. There is growing evidence that the latest era of technical advance has run its course. The last five years have been an unmitigated disaster for American farmers and for large segments of the agricultural inputs industry. Net farm income has plummeted and bankruptcies have risen as high interest rates, rapidly climbing land costs and low commodity prices cut into on-farm profits. Declining productivity has made it difficult or impossible for the farmer to escape this classic cost-price squeeze. The twin oil shocks of the seventies, a soybean embargo against the Japanese in 1973, and the recent grain embargo directed at the Soviet Union have exacerbated the problem. Endemic overproduction has reached monumental proportions even as agricultural commodities have become an ever more important component of our balance of payments, accounting for 20 percent of total exports. The much vaunted American food weapon is becoming a state-subsidized albatross which permits and encourages increased production even though the commodities cannot be realized in the marketplace.

But capitalism is nothing if not resilient, and we believe that new social arrangements in agriculture are already being prepared. These novel social relations are being generated and shaped by the development of new productive forces. The most important of these with regard to agriculture is the constellation of novel techniques popularly and generically referred to as "biotechnology".

Though yet an embryonic technical form, we believe that biotechnology has already set in motion a major restructuring of the agricultural sector(1). The elements of this restructuring would appear to include:

1. an accelerated centralization of capital among agribusiness firms and the integration of the seed (genetic supply) industry with the chemical and pharmaceutical sectors;

2. the establishment by non-farm capital of unprecedented control over the determination of the agricultural production process via the seed;

3. the redefinition of the roles of national and international agricultural research agencies to minimize the contradictions between public and private plant breeding and to allow corporate capital to be directly serviced by public research laboratories;

4. the emergence of the fundamental strategic importance of genetic conservation and increasing monopoly control over genetic resources;

5. the replacement of a stagnant "Green Revolution" with a "Bio-Revolution" in the Less Developed Countries (LDCs); Whereas the Green Revolution led to large gains for capital in selected areas, the Bio-Revolution will permit the penetration of capitalist relations in agriculture to be extended to all regions, including those characterized by marginal soils where subsistence and petty commodity production persist.

Our aim is to elucidate the operation of the laws of motion of capitalism in the world agricultural system and [illegible]ll [illegible]

mobilization of popular efforts to confront the new corporate challenge associated with the development of biotechnology.

Capitalism and the Farmer

American agricultural productivity increased dramatically following World War II. Three different vectors of technological change drove this process (Cochrane, 1979:202). The first of these was mechanization. In the decade after 1940 mechanical power replaced human and animal muscle in nearly every facet of the production process. Plant breeding, itself really a "biotechnology", constituted a second principal area of development. The introduction of improved plant varieties contributed significantly to increased crop yields. But most of the productivity advance of the post-war era came as a result of the application of petrochemicals: herbicides, insecticides, fungicides and especially fertilizers (Brady, 1982:847).

Of these three principal technical thrusts the land grant universities (LGUs) undertook the central responsibility for research and development only in the case of plant breeding (Buttel, 1981:13). Thus, the two most important components of technological change in agriculture have been the product of entrepreneurial capitalism rather than public research (Lewontin, 1982:14). Since 1940 the involvement of non-farm sectors in providing agricultural inputs — fertilizer, pesticides, machinery, oil, finance — has expanded tremendously (Goss et al, 1980:97).

At the center of these technological changes is the farmer, a producer who has not yet been expropriated by capital. Many scholars have sought to explain the failure of capitalism to fully penetrate farming (as opposed to agriculture, broadly construed) (see for example, Mann and Dickinson, 1978; Davis, 1980; Lewontin, 1982). While a variety of explanations for this phenomenon have been advanced, the most persuasive focus on several unique characteristics exhibited by the agricultural production process: it is physically extensive and labor is difficult to control, there is a non-identity of production and labor time so production is discontinuous and turnover rate of capital is slow, there are unavoidable and unpredictable risks associated with the weather, pests, and diseases, and the need to purchase land ties up capital unproductively. For a variety of reasons agricultural production fails to return the necessary average rate of profit even under large scale corporate management (Buttel, 1981:11; Cordtz, 1972).

The resistance to capitalist penetration evinced by farming has meant that the farmer has retained a measure of autonomy in determining the form of the production process. He has not, however, been immune to domination by capital. In a number of crops agribusiness corporations have gained a modicum of control over the production process through such mechanisms as contract farming (see Davis, 1980; Pfeffer, 1982). Capitalists are seen to subjugate the independent producer by virtue of their control over the market for commodities. In this sense the farmer is a "contract taker" as well as a "price taker" and may be forced to modify planting, harvesting and cultural operations to meet corporate parameters. Such arrangements have proven more satisfactory to capital than engaging in actual production and operating a farm.

The enormous political strength of the agricultural sector in the advanced capitalist nations also deserves note. A striking manifestation of this strength is the Land Grant University (LGU) system and the USDA Agricultural Research System (ARS), both of which are almost entirely subsidized by state and federal governments. Because the public agricultural research agencies tend to work on immediate and short term problems, the solutions to which generally involve the use of additional manufactured inputs, agribusiness has not had to attempt to define public research agendas (Buttel, 1981:16). The LGU and ARS systems have remained decentralized, responsive to farmer needs ("progressive" farmers, of course) and relatively autonomous from corporate influence. Their principal function has been plant breeding in non-hybrid crops. This area has not been attractive to capital because seed prices in pure line crops cannot deviate far from bulk grain prices since the farmer has the option of saving harvested seed for the next year's planting.

The post-war advances in agricultural technologies were made manifest in the LDCs via the "Green Revolution" of the 1960s and 1970s. Ostensibly a response to the spectre of famine in the developing nations, the Green Revolution had political and eonomic objectives no less important than its philanthropic ones: to head off a "Red Revolution" and to facilitate the penetration of the countryside by capital. In essence, the Green Revolution involved the development and introduction of high yielding crop varieties (HYVs), principally rice and wheat, for the purpose of increasing food production. The institutional core of the program was the establishment in the late 1950s of a series of International Agricultural Research Centers (IARCs) with Rockefeller and Ford Foundation financing. These centers are reminiscent of public agricultural research agencies in the United States not only in their concentration on plant breeding, but in their "mission" orientation and their ideological commitment to public service.

The varieties developed by the IARCs also reflected American practice; the Green Revolution strategy explicitly emphasized yield improvement by breeding HYVs for the best lands, with the use of irrigation, fertilizers and pesticides (Plucknett and Smith, 1982:216). The new seeds did indeed produce greatly increased yields - provided the requisite inputs were available (note that in the years preceding the launching of the Green Revolution the world was in the throes of both petroleum and fertilizer gluts). Farmers wishing to adopt the HYVs were compelled to purchase the complementary inputs. In this fashion capitalist market relations were introduced and promulgated, and new sources of profits generated for transnational agribusiness. Not all peasants and farmers could afford the needed inputs and as the HYVs stimulated land values large numbers of tenants were driven from the land. Income disparities were exacerbated both within and among regions (see, for example, Cleaver, 1972; Perelman, 1977; and the extensive debate in the Indian journal Economic and Political Weekly). Furthermore, traditional varieties and crops such as millet and sorghum were often displaced, initiating a process of genetic erosion the magnitude of which is only now being fully understood.

Thus, the Green Revolution has succeeded in creating in many of the LDCs a capitalist farming sector based on wage labor and the extensive use of purchased inputs. However, the HYVs have been largely limited to areas of good soil and infrastructural development sufficient to permit input delivery. Adoption of HYVs apparently slowed in the late 1970s and vast areas of poorer land in the Third World have not been planted to the improved varieties (Plucknett and Smith 1982:216). In an effort to maintain the momentum of the Green Revolution the number of IARCs has been expanded to 13 and the operations of these institutions are now coordinated by the Consultative Group on International Agricultural Research (CGIAR) which acts on behalf of some 34 donors and is headquartered in the World Bank.

The New Biotechnologies

In 1974 Stanford and University of California, San Francisco researchers Stanley Cohen and Herbert Boyer succeeded in removing a DNA sequence from a gene of one organism and inserting it into the genetic coding of another. Together with breakthroughs in cell and tissue culture this achievement opened a vast new frontier for those industries in which biological processes and organic chemicals are important components of the production process (OTA, 1981). Rather than a purely empirical or descriptive knowledge of life processes, a new understanding based on a precise knowledge of the operation of organisms became possible. The key to understanding the new biotechnology is to think of the DNA in every cell as information, a program which controls the behavior of that cell.

The manipulation and alteration of the genetic or cellular integrity of an organism in order to create novel forms engineered for specific functions promise to revolutionize chemical and pharmaceutical development and production, pollution and waste management, energy generation, food processing, and plant and animal breeding. The market for agriculturally-related genetic engineering products and processes is expected to surpass even that for medical/pharmaceutical applications, and sales for the agricultural sector alone are projected to reach \$50-\$100 billion annually by the year 2000 (Sheasley, 1981:23).

Biotechnology introduces the reality of vastly more efficient breeding and selection methods in the short run, and the possibility of fully engineered plants in the long run. Advances in tissue culture and protoplast fusion have already greatly enhanced the speed and efficiency of conventional breeding programs (Meredith, 1982). Clonal propagation of asexually reproduced species ensures disease free plant material and reduces the time needed to grow out planting stock by as much as a factor of 30 (Strohl, 1981:43). Such procedures have already had a commercial impact on oil palms, cassava, potatoes, strawberries and even redwood trees. The new techniques profoundly affect the breeding of sexually reproduced species as well. Tissue culture and related procedures enable the evaluation of germplasm and the selection of desireable characteristics to be performed on a growing mass of cells in a petrie dish rather than on actual plants in the field (<u>Crops and Soils Magazine</u>, 1982:17; Shepard, 1982:157). Such procedures reduce by half the 10 to 12 years traditionally needed to develop a new crop variety.

But it is the potential capacity to wholly circumvent conventional barriers of genetic incompatibility which gives biotechnology in agriculture its truly revolutionary character (Schmeck, 1982). It should be possible to move genes controlling particular features between varieties and even between species; that is, to actually design novel plant varieties engineered to meet specific economic goals. While such engineered varieties have not yet been developed, both the corporate giants and the venture capital rDNA firms are assiduously pursuing their development across the entire spectrum of commercial crops. Principal areas of research include nitrogen fixation, stress tolerance (especially to cold, moisture, salinity and aluminum toxicity), disease and pest resistance, enhanced photosynthetic efficiency, growth regulation, herbicide immunity, and, of course, hybridization in pure-line crops. Forecasts of when engineered varieties might be available have varied widely, but there is a growing consensus among researchers that initial commercial applications will be realized within a decade (Pramik, 1982:15; <u>Seedsmen's Digest</u>, 1982c:8).

<u>Centralization of the Agricultural Inputs Sector</u>

Galvanized by continued scientific advances and the broad range of sectors over which the new bioengineering techniques are commercially exploitable, business interests have made massive investments in biotechnology. In the last few years the establishment of small genetic engineering research firms has attracted extensive attention in the business, scientific, trade and popular media (e.g., Bylinsky, 1980; Walsh, 1981; Wittwer, 1982; Cowen, 1981). Transnational corporations such as Allied, American Cyanamid, ARCO, Chevron, Ciba-Geigy, Dow,

... new opportunities by purchasing equity interests in the venture firms, and by rapidly enhancing their in-house research and development capabilities with regard to bioengineering.

Many of these same companies have also attracted attention for their participation in the wave of acquisitions and mergers that has been sweeping the seed industry (Mooney, 1979; Fowler, 1980). Since 1973 over 50 seed companies have undergone changes of ownership (Davenport, 1981:9). Of the principal American seed firms only Pioneer Hi-Bred has maintained its independence. Such well known companies as Northrup King, Asgrow, Trojan, and Funk have been absorbed into the corporate folds of transnational petrochemical and pharmaceutical giants (Table 1), and DeKalb Ag Research has undertaken a joint venture with Pfizer Genetics.

Table 1 about here.

Seed company acquisitions were initially independent of onsideration relating to biotechnology and many of the most significant ransactions occurred prior to 1976, before the bio-boom took hold. It as the 1970 passage of the Plant Variety Protection Act (PVPA), xtending patent-like protection to newly developed non-hybrid plant rieties, which touched off the scramble. But those agrochemical oducers that puchased seed companies in the first half of the 1970s day find themselves uniquely poised to take advantage of the otechnological revolution in agriculture. Biotechnology has inforced the acquisition trend and given it new urgency.

Table 1. Some Recent Seed Company Acquisitions and Characteristics of Acquiring Firms

Acquiring Company:	Seed Subsidiaries:	In-house Biotech:	Biotech Venture Firm Interests:
ARCO	Dessert Seed Co	X	IPRI Ingene Bioengineering Center
Celanese	Celpril, Inc Moran Seeds Joseph Harris Seed Co.	X	
Ciba-Geigy	Ciba Geigy Seeds Funk Seeds Louisiana Seeds Hybridex	X	
FMC Corporation	Seed Research Associates	X	Centocor Immunorex
Monsanto	Farmers Hybrid Co.	X	Genex Biogen Genentech Collagen
Occidental Petroleum	Ring Around Products Excel Hybrid Missouri Seeds Moss Seeds	X	
Pfizer	Trojan Seed Co. Jordan Wholesale Co. Clemens Seed Farms Warwick Seeds	X	
Sandoz	Northrup King National N-K McNair Seeds Gallatin Valley Rogers Brothers Ladner Beta	X	Zoecon
Shell	North American Plant Breeders Nickerson Seed Co. Agripro, Inc. Tekseed Hybrid	X	Cetus
Stauffer	Stauffer Seeds Blaney Farms Prairie Valley	X	
Upjohn	Asgrow Seeds Associated Seeds	X	

The trend to integration of the agrochemical and seed industries has an inherent and compelling logic. The plant breeder and the agrochemical researcher are frequently working on the same problem, albeit from different perspectives, and chemical solutions (e.g., growth regulators, pollen sterilants, etc.) have often been sought for difficulties which appeared intractable to the breeder.

Research and development in the seed companies and their parent corporations has profound synergistic potential. The genetic manipulation of bacteria, for example, is relevant to both the refinement of industrial fermentation processes and to the improvement of nitrogen-fixing microbes which inhabit the roots of certain crops. Research in one area may well have important and unexpected significance for work in another. For example, human interferon has recently been found to be an effective fungicide (New Scientist, 1982a:554). Biotechnology has in large measure dissolved the boundaries between the chemical and biological inputs sectors in agriculture and welded their products as well as their producers. There are tremendous opportunities to rationalize and coordinate research, development and marketing of the full range of agricultural inputs.

The seed is the form in which biotechnological research in arable agriculture must be realized. It is important to understand that the techniques of genetic engineering complement and expand rather than supersede conventional plant breeding methods. The need for the traditional plant breeder has not been eliminated, nor is it likely to be. Except for a few vegetatively propagated crops, there is no way to bring a new variety to the consumer except via the seed. The seed is itself the end product of the entire research and development program and it is as a seed that the plant must enter the market.

Thus, a plant breeding capability, seed production and processing facilities, and distribution and marketing networks are critical to the rapid and efficient commercialization of biotechnology in arable agriculture. It is these features which the large petrochemicals and pharmaceuticals now enjoy through their recent and continuing acquisitions of established seed companies. Purchase of the Joseph Harris Seed Company in 1979 provided Celanese with the Carl L. Warren Laboratory, a cadre of 30 experienced researchers, an extensive proprietary collection of vegetable germplasm, and an established clientele. By acquiring Funk Seeds in 1976, Ciba Geigy gained control of a company with a strong position in the lucrative seed corn market and extensive international research and marketing facilities. Seed companies, and by extension their transnational parents, are capable of setting their own breeding agendas according to their own criteria -- profitability.

The Seed: Nexus of the Production Process

Critics of the PVPA have seen the Act as the catalyst permitting the consummation of what they regard as an unholy marriage between the chemical and seed industries (Mooney, 1978; Fowler, 1980). In particular they fear the institution of a "chemical bias" whereby the transnational corporations will encourage their seed company subsidiaries to develop plant varieties requiring large inputs of fertilizer and pesticide, in which they hold substantial interests. While such concerns are not without validity, they do not adequately reflect the technological transformation of the past few years. The powerful synergy which biotechnology confers on the chemical/seed linkage and the revolutionary potentials inherent in genetic engineering raise the issue to a qualitatively different plane: what is at issue now is not mere fertilizer-pesticide "bias", but the possibility of establishing a high degree of control over the determination of the agricultural production process itself.

As it matures, biotechnology will permit plant breeding agendas to be set with unprecedented specificity. In seeds are encoded the programs which control the biosynthetic processes by which plants develop and respond to the environment. To the extent that genetic engineering permits the reprogramming of detailed parts of the genetic code, plant breeders and molecular biologists will be able to determine where the plant may be grown, under what environmental conditions, the requisite inputs, the timing of cultural and labor activities, the mode of harvest, the manner of processing, and, of course, the characteristics and quality of the vegetable product itself. In sum, the seed becomes the nexus of control over the determination and shape of the production process in agriculture.

Though agricultural genetic engineering is still an embryonic technology, the trajectory of its application to production processes can already be discerned. Biotechnology holds out the possibility of designing plants in such a way that they are complemented by selected chemicals or organisms, and vice versa. The systematic search for herbicide antidotes and timed release fertilizers in which the agrochemical corporations have been engaged, has begun to yield results (Geissbuhler et al., 1982:507). Funk Seeds has introduced eight [illegible]ally [illegible]ted [illegible]m v[illegible]es [illegible] ma[illegible]fely [illegible]ive

applications of parent Ciba-Geigy's proprietary herbicides (<u>Farm Chemicals</u>, 1979:55). Northrup King (Sandoz) is close to commercializing herbicide-coated alfalfa seed (<u>World Crops</u>, 1982:30). Industry spokesmen are quite explicit regarding their strategic intentions. Dr. Klaus Saegebarth, DuPont's director of agrichemicals research, sees "the breadth of DuPont's line of crop protection chemicals as literally representing a DuPont Crop Management System" (<u>Farm Chemicals</u>, 1981:21).

The dominant position among giant pharmaceutical and petrochemical firms with regard to biotechnology ensures that the plant/chemical inputs linkage will exert a powerful influence on future development of genetically engineered crop varieties. Important though it is, it would be a mistake to focus exclusively on this feature. Having gained access to the instructions encoded in the DNA at the molecular level, a "package" approach to crop development potentially encompasses any or all plant traits relevant to the production process including, but by no means limited to, response to chemical inputs.

In addition to investigation into herbicide resistance, pesticide compatibility, and chemical growth regulation, both private and public plant breeders are using the techniques of genetic engineering to focus research on an array of important agronomic traits including plant architecture, harvestability, maturation, photo-period, stress (temperature, moisture, soil chemical, soil structure) tolerance, photosynthetic efficiency, nutrient utilization, disease resistance and nutritional quality. As biotechnology enhances control over the particular form the expression of these features takes, specific varieties will be developed for specific purposes. Such varieties will be complex, detailed, and carefully balanced combinations of agronomic traits. As such, they will require the application of sophisticated variety specific management and monitoring packages if their productive potential is to be realized (Hanway, 1978b:5) (2).

Up to the present the farmer has retained a substantial degree of control over the farm production process and his own labor process. Biotechnology permits the external determination of these processes by their embodiment in the seed itself. It would be naive to think that control over the seed by transnational agribusiness will not be used to establish and defend market positions in proprietary input packages. In selecting the seed of a particular plant variety the farmer will in essence also be choosing his entire production process. Control may be exerted from both the input and product stages, for a number of food processors have joined the inputs corporations as owners of seed companies and investors in biotechnology. The farmer will certainly become more deeply enmeshed in the web of contractual relations which bind him to large-scale capital. Contractual integration will become more widespread and the contracts themselves will be more stringent. Processors frequently specify the variety to be grown and, in an arrangement known as "bailment", the processor also supplies the seed and retains title to both the seed and the crop which grows from it (Pfeffer, 1982:77). Biotechnology will help render the farmer ever more a "propertied laborer" (Davis, 1980): on the one hand a landlord and on the other a laborer who cares for corporate plants.

The Changing Role of Public Agricultural Research

The potentially determinate relationship between the seed and agricultural production processes which is emerging from biotechnological advances makes control over plant breeding an item of paramount importance. Yet this is the very area in which public agricultural research agencies enjoy a measure of preeminence vis a vis private industry. However, capital achieved a major precondition for the effacement of public research in 1970 with passage of the PVPA. Since that time seed companies have been attempting to redefine the role that is played by the public breeder (see Roberts, 1979; Sprague, 1980; Pardee et al., 1981; Peterson, 1981; Leffel, 1982; Ruttan, 1982). Biotechnology renders the need for capital to circumscribe public breeding activities yet more urgent, for the seed is now the gateway to control over the production process as a whole.

Prior to the enactment of the PVPA, varietal development in pure-line (non-hybrid) crops was almost exclusively the province of the public breeder. The activities of private companies in these crops were mostly limited to the production, processing and marketing of the seed of "college bred" varieties (Christensen, 1957; White, 1959; Copeland, 1976:214; Duvick, 1982:34; Padwa, 1982:98). Without some form of patent-like protection there was little incentive for the investment of private capital in the costly and time-consuming process of research and varietal development. However, when hybrid corn was introduced in the 1920s seed companies had taken advantage of the "natural" protection provided by proprietary control of inbred parents and moved quickly to displace the public development of commercial corn lines (Ruttan, 1982:25). With the example of the profits possible in hybrid corn before them, seedsmen sought to gain "breeder's rights" by legislative fiat. In 1970, despite the lack of evidence that public breeding had been anything but "remarkably effective" (Ruttan, 1982:25), the PVPA became law.

Industry would like to see the activities of the public sector confined exclusively to those areas not attractive to private investment: education and training, the evaluation and development of germplasm, and basic research. Applied research, by which is meant the release of finished commercializable varieties, is explicity seen to be the responsibility of the private sector (Roberts, 1979:45). The elimination of "duplicative" and "redundant" public research would give private industry virtually complete control over all crop varieties entering the market. Reduced to the provision of inbred lines to private breeders they themselves had trained, the land grant universities would provide a cheap subsidy to the seed industry which would then extract high profits from farmers.

Though publicly developed lines yet account for more than 80 percent of the varieties of rye, wheat, oats, soybeans, rice, barley and peanuts used in commercial production (Hanway, 1978:5), public agency hegemony in plant breeding is being steadily eroded. Fully 86 percent of the varieties receiving protection over the first decade following enactment of the PVPA were bred by private companies. The USDA's Agricultural Research Service has made disengagement from applied breeding one of its institutional objectives (Skarien, 1982:6).

The Experiment Stations and the land grant universities (LGUs) are hard pressed even to maintain current levels of activity. Public institutions face declining state and federal aid for plant breeding research. They are finding it increasingly difficult to recruit and retain staff and to keep operating funds at a reasonable level (Peterson, 1981:24; Pardee et al., 1982:9). Several state programs have already shifted their focus from varietal development to germplasm development and population improvement, and a general trend to enhanced cooperation with corporate breeding is evident (Hanway, 1978:6). With some 56 private companies currently constituting the National Council of Commercial Plant Breeders, the LGUs are under continuous pressure to abandon those areas of research which can profitably be undertaken by private enterprise.

Corporate interest in biotechnology has also stimulated the formation of unprecedented linkages between private companies and universities (for a full discussion see Kenney et al., 1982). Such arrangements, while allowing scientists to remain within the university, introduce important conflicts of interest and secrecy concerns into the academic environment. University breeding programs, where not weakened by loss of personnel to expanding private breeding concerns, are brought increasingly under corporate influence. It would appear unlikely that public breeding programs, many of which are already in financial straits, will be in a position to exploit the new technologies as rapidly or easily as private industry. Should genetic engineering become an integral part of crop improvement the LGUs and the experiment stations may even find themselves with plant breeding—or engin[illegible]—ca[illegible]ies [illegible]edly [illegible]ior [illegible]ose [illegible] private sector. Under such conditions public agricultural institutions would have little choice but to engage in the residual activities which private capital chooses not to undertake.

For all its promise, genetic engineering is as yet an embryonic technology. The outcome of any one line of research is highly uncertain and while progress is being made daily there are yet many fundamental problems to be overcome and much research to be undertaken before extensive commercialization of "engineered" products can be realized (Rachie and Lyman, 1981; Nilan, 1981). The concrete imperative of profitability makes absorption of expensive and indeterminate basic research costs by the government a desirable option from the corporate point of view. Yet the present structure of the USDA and the LGU system is not geared to the efficient pursuit of the new lines of research which advances in biological knowledge have opened up. It is to this constraint that the corporations and their institutional allies have now turned.

The Rockefeller Foundation and the White House Office of Science and Technology Policy (OSTP) recently issued a joint report (3) bluntly indicting the USDA for its parochialism, bureaucratic rigidity, regional geopolitics, and inability to identify research areas of critical importance. A substantial portion of the problem is attributed to the dispersed and decentralized nature of the Agricultural Research Service and to lack of control over the block grants which support research in the land-grant universities and associated state experiment stations. The report recommends a restructuring of the American agricultural research system. The principal features of this realignment would be the consolidation and rationalization of ARS stations and programs, a

concentration on basic "cutting edge" biological research, and the expansion of the currently modest competitive grants program (The Rockefeller Foundation 1982).

Implementation of the recommendations could well result in a transformed LGU system that is increasingly replaced by a structure based on the Rockefeller model of highly centralized research facilities in a few locations (Kohler, 1976). The new system of "managed" and "rationalized" research would function to serve corporate capital which would be permitted to determine research goals. The Rockefeller/OSTP report (1982:26) asserts that

> Private sector expertise should be fully utilized in efforts by the public sector to identify future research needs, estimate future demand for scientific and technical manpower, and define appropriate, complementary roles and responsibilities for the various sectors and institutions involved in science for agriculture. Mechanisms should be developed for strengthening the linkages between the findings of basic and applied research performed in the public sector and their development and commercialization by industry.

Tellingly, no mention is made of the role of farmers, labor, consumers, or environmental groups. Stimulated by the revolutionary potential of biotechnology, capital is attempting to establish control not only over the crucial plant breeding process, but over the shape of basic research as well (for further discussion see Kenney and Kloppenburg, forthcoming).

Genetic Vulnerability

An issue which has received much attention in recent years is that of genetic vulnerability. Assertions to the contrary (Mooney, 1979; Fowler, 1980; Schapiro, 1982) notwithstanding, seed companies and their transnational parents are interested in preserving and enlarging, not narrowing, the genetic diversity available to plant breeders. Germplasm is, after all, the breeder's raw material. The continual development of new varieties in response to competitive pressure and to changes in the disease, pest or climatic spectra requires a substantial collection of germplasm from which to work. Neither the corporate nor the public breeder has an interest in intentional genetic erosion. Why then does Pioneer sell hybrid corn to the Mexican campesino, thus displacing traditional varieties? And why is it that the National Academy of Sciences can call American crops "impressively uniform genetically and impressively vulnerable"?

The answer is to be found not in the PVPA but in the very nature of capitalist competition. Whatever Pioneer's ultimate interest in the preservation of native varieties of Mexican maize, the concrete imperatives of competition and profitability will drive the company to sell hybrids to the Mexican farmer, thus overriding long-term genetic diversity considerations. Worldwide, genetic erosion will continue; traditional cultivars will continue to be replaced by commercial varieties. Similar pressures act on the American farmer as well. In general the farmer must select the highest yielding seed available since he is also driven by the profit motive. Choices are not made on the basis of the public interest, for only those who outproduce their competitors survive.

Thus, <u>the market itself produces a lack of genetic diversity</u> in the crop varieties being grown at any given time. In the absence of national agricultural planning or of controls on seed companies or farmers, the best we can do is to keep our germplasm banks filled and to maintain our research capabilities at such levels as will permit us to deal effectively and quickly with such problems as arise.

The American seed industry clearly supports germplasm collection and preservation and has a major influence on international and domestic policies through representation on both the International Board for Plant Genetic Resources and the National Plant Genetic Resources Board. Private companies currently maintain extensive proprietary genetic collections of their own and support the strengthening of the National Seed Storage Laboratory (NSSL) and associated facilities. Though private companies will willingly permit the government to subsidize the storage and preservation of the bulk of national germplasm resources, they are unlikely to submit their own advanced breeding lines to the NSSL since its collection is open to any bona fide researcher.

Seed companies have historically not been as deeply involved as public agencies in plant exploration, the collection of wild varieties, or in the basic screening and evaluation of such materials. These costly activities will probably remain the province of the government and the LGUs. How much of the current universe of world germplasm will be preserved will largely be determined by how well public agencies fulfill this role (4). The potential consequences of an inadequate pool of [illegible]c re[illegible] is [illegible]dely [illegible]gnized [illegible]n, 1[illegible]). Since all of the principal crops grown in the United States and most advanced capitalist nations are native to other parts of the world, American germplasm collection teams are currently scouring the world for useful materials (Diversity, 1982:14; Vicker, 1982:54).

Such plant genetic resources, acquired free of charge from the gene-rich LDCs, can be worth a great deal. Incorporation of an Ethiopian gene conferring striped rust resistance into American barley varieties has saved U. S. farmers an estimated $150 million per year (New Scientist, 1982b:218). In a classic example of imperialism, these varieties are sold back to the very nations which furnished the genetic material at no charge in the first place. Pressures on the LDCs to institute variety protection legislation similar to that in the developed world are being applied by the FAO and the International Board for the Protection of Plant Genetic Resources. Such legislation would ease commercial access to LDC seed markets and greatly enlarge possibilities for profit. Genetic material will increasingly be recognized as a strategic resource. Already some LDCs have closed their borders to plant hunters and, despite an avowed policy of free access, the United States has refused certain nations access to genetic material in the National Seed Storage Laboratory on political grounds.

Biotechnology could, however, significantly alleviate many of the problems associated with genetic vulnerability. Of the germplasm already in American collections only a very small proportion has actually been evaluated. The genetic variability available in corn is perhaps the best documented, yet 90 percent of the germplasm available for that crop has not been utilized as a source of varietal improvement (Zuber and Darrah, 1980:248). Much of the genetic resources currently available are unuseable because breeders simply don't know their characteristics. The new genetic technology allows the evaluation of 100 million cells, each a potential plant, in a single petric dish (Meredith, 1982:6). Enormous savings in time, space and money will permit extensive evaluation of current germplasm accessions, thereby greatly expanding the genetic material available to the breeder in practical form.

Such savings apply to the actual process of breeding as well as to germplasm evaluation. Moreover, biotechnology will further extend the genetic diversity available to the plant breeder by allowing the incorporation of traits from different species and, ultimately perhaps, from other organisms. Breeders will no longer be limited by the heretofore rigid parameter of speciation. Not only are mutagenic techniques improved by biotechnology, but variability can actually be engineered via protoplast fusion and rDNA transfers (Nilan, 1981:29; Padwa, 1982:101). Advances associated with genetic engineering may also reduce genetic vulnerability by permitting the selection or construction of plants with multiple tolerance genes ("horizontal" resistance) rather than unstable single gene ("vertical") resistance (Orton, 1982:23).

However, if genetic engineering addresses many of the material consequences of genetic erosion, it will not halt the process of erosion itself since that is a product of capitalist competition. In this sense biotechnology treats the symptoms rather than the disease. If the new technologies are viewed as a solution rather than as a palliative, genetic engineers and plant breeders may yet find themselves without sufficient genetic resources to deal with crises of genetic vulnerability.

A "Bio-Revolution" in the LDCs?

There has been widespread recognition of the potential value of biotechnology to the LDCs (Plucknett and Smith, 1981; Gandhi 1982; Brady, 1982; Bodde, 1982). India and the Philippines have established national institutes of biotechnology, and at the request of the U. S. Agency for International Development the National Academy of Sciences has convened a conference on "Priorities in Biotechnology Research for International Development" (Swaminathan, 1982). Visions of a "bio-revolution" to take up where the Green Revolution left off are already commonplace (Sojka, 1981).

Would such a bio-revolution have a more positive impact on the poor of the LDCs than did the Green Revolution? Much would appear to depend on the role and strategy undertaken by the International Agricultural Research Centers (IARCs). Even assuming that the IARCs are suitable agencies for the development and introduction of socioeconomically desirable bioengineered plant varieties, there is reason to doubt that they will be in a position to assume this responsibility. The changing articulation of public and private plant breeding in the advanced capitalist nations is having parallel effects on international institutions.

The IARCs currently find themselves in financial straits akin to those suffered by the American land grant system. Funding for the IARCs in 1983 will fall short of inflation by 6 percent and virtually all 13 centers are cutting back on research and training programs (Lewin, 1982; Plucknett and Smith, 1982). They are also turning increasingly to arrangements which are highly [illegible] tage[illegible] pri[illegible] apit[illegible] or

example, CIMMYT, the Mexico-based international maize and wheat research institute where Norman Borlaug did his Nobel Prize-winning work, has found it necessary to ask Pioneer Hi-Bred to grow out its varieties for purposes of maintaining the viability of its germplasm collection — an expensive process CIMMYT could not afford (Diversity, 1982). In return, Pioneer is allowed to retain a copy of all genetic material it reproduces. As with the LGU system, the IARCs will receive new tasks as their budgets are decreased.

Transnational agribusiness clearly views the Third World as both a lucrative market for bioengineered products and a source of much needed genetic diversity. With the plant breeding process itself becoming a crucial link in the valorization of biotechnology research, private industry may well find it useful to confine the IARCs, based as they are in the LDCs and espousing the ideology of working for the common good, to basic research and the collection, preservation and evaluation of germplasm. The shape of the Bio-Revolution will ultimately be determined by the needs of transnational capital.

Bioengineered crop varieties adapted to low levels of fertility or tolerant of saline conditions could raise productivity in vast areas of marginal land where conventional HYVs are not suitable. In the Green Revolution the poor were driven from the good land by the developing capitalist sector; the Bio-Revolution will extend the process of displacement to heretofore marginal areas where subsistence and petty commodity production has persisted. Clonal propagation of improved tree crops could greatly alleviate fuelwood and deforestation problems, but these are not the uses to which genetic engineering is being put. It is the large plantation owners and forestry corporations such as Unilever, Sime Darby, and Weyerhauser that have access to the new technology and their goal is simply profit. Tissue culture has reduced the time necessary to develop improved oil palm varieties by a factor of 30. Thousands of micropropagated oil palms, designed to be uniformly short to reduce labor costs, have already been planted on the commercial plantations of Southeast Asia (Strohl, 1981).

Introduction of engineered plant varieties may also have far-reaching effects on the international division of labor in agriculture. The tropics have a number of advantages over temperate zones including year round warmth and more intense sunlight. Biotechnology could conceivably permit the development of varieties of, say, corn or soybeans amenable to continuous culture outside the temperate zone — with devastating effect on the farmers of North America and Europe. On the other hand, industrial applications of biotechnology have already had negative impacts on markets for LDC sugar, pyrethrums (organic pesticides derived from a member of the daisy family) and opiates as bioengineering techniques permit the production of substitute or synthetic commodities. For example, development of immobilized enzymes in the early 1970s slashed production costs of high fructose corn syrup by 40 percent, devastating the cane sugar market. In 1982 corn syrup accounted for 38 percent of the industrial sweetener market and by 1987 this figure is expected to rise to at least 60 percent (Hannigan, 1982:77).

Moreover, the development of tissue culture techniques is making possible the industrial production of medicinal products formerly only derivable from whole plants or synthetic processes involving expensive petrochemicals. Tissue culture, the growing of plant or animal cells in a nutrient medium, allows individual cells to produce substances in isolation from the remainder of the original organism. The cells produce the desired substance which is then extracted. The increased capital intensity of this production process is obvious: no plants to be planted, husbanded and harvested; lower transportation and processing costs, and better quality control. Production becomes more predictable and dependable, and is no longer even "agriculture." Many products will be affected in this fashion by tissue culture developments. In each case workers will be displaced and many LDCs will find markets for their agricultural commodities being eroded by bio-industrial substitutes.

Political Initiatives

At present private enterprise operates under minimal constraints in the development and commercialization of the new biotechnologies. It is imperative that citizen's groups gain an understanding of and a significant measure of control over the manner in which the world's gene pool will be exploited. We have tried in this paper to establish the trajectories along which biotechnology in agriculture will likely be implemented, and to explore the impact that biotechnical innovation could have on the organization of production and the structure of the world agricultural system. It should be clear that if capitalist designs for the deployment and commercialization of biotechnology are not modified there will be serious consequences for the environment and for farmers and agricultural workers of both the LDCs and the advanced capitalist nations.

The advent of genetic engineering has already sparked a number of controversies which have received significant public attention. Ever since the perfection of techniques of DNA recombination in the 1970s, genetic engineers have had to contend with criticisms from environmental groups regarding the possibility of ecological disaster should genetically modified organisms escape containment. Some city governments have gone so far as to apply zoning regulations in an attempt to restrict and control rDNA research (see Krimsky, 1982). The ethical implications of the manipulation of life forms, and especially prospects for "engineering" the human species, have attracted the concern of many humanitarian and religious organizations. Plant patent legislation such as the American PVPA and similar bills now pending in Canada and Australia continue to arouse populist anti-corporate sentiment and to elicit important opposition from such U. S. groups as the National Sharecroppers Fund and the People's Business Commisssion.

Though concerns with the environment, ethics, and patent law are extremely important and have established a popular base of opposition to the unregulated commercialization of biotechnology, a more strategic focus for struggle may be the battle for control over the direction and uses of publicly funded research. Biotechnology has in some ways dissolved the distinction between basic and applied science. The goals established in basic research directly and materially condition the form of the final product and the possibilities of commercialization. Capi[illegible]s cl[illegible]ecog[illegible]this [illegible]tion[illegible]s now[illegible]mpting [illegible]

restructure the public agricultural research apparatus to its own specifications. Defending the relative autonomy of the university from this assault is a prerequisite to gaining social control over the direction future research will take.

If the commercial potential of biotechnology has made private industry eager to buy access to academic research, declining levels of government support have rendered university administrators more than willing to consummate the transaction. Critics of the accelerating penetration of the university by capital found a public forum for their concerns in hearings before Congressman Albert Gore (U. S. House of Representatives 1981). More recently, Ralph Nader, Albert Meyerhoff, and David Noble have formed the Special Commission on the Corporate Control of Academic Science (5) in order to lobby for the creation of "a democratic mechanism that would oversee university-based research activities in order to render science and technology compatible with democracy and the public interest" (Noble 1983:52). With a similar end in mind the California Rural Legal Assistance (CRLA) agency has already undertaken direct action. Addressing possible conflicts of interest, CRLA sued the University of California to force faculty members to disclose their financial interests in private companies supporting their research (Divoky 1983:B2).

Congressman Gore's subcommittee has also been the arena for discussions regarding the possibility of using newly developed biotechnical procedures to genetically sqreen workers for susceptibility to diseases associated with the industrial environment (U. S. House of [illegible]sent[illegible] 198[illegible] Selec[illegible] of [illegible]or [illegible] "tole[illegible]" of workplace conditions is [illegible] prospect of new forms of managerial control and employment discrimination has begun to awaken labor organizations to the importance of biotechnology and to the uses to which it can be put. Representatives of a variety of labor, consumer, academic, and environmental groups have recently established the Committee for Responsible Genetics (6). This organization will function as a clearing-house for the exchange of information among citizens' and public interest groups addressing the far-reaching political, economic, environmental, and ethical questions posed by the new biotechnologies.

Biotechnology is pregnant with potential for both liberation and domination. Which way it develops will depend upon who wields it and upon the parameters that society can establish to guide its use. We hope that other researchers will find in our paper an agenda for further study and a basis of information with which to build struggle against capitalist hegemony. The time for action is now — before the new technologies are irretrievably deployed.

Footnotes

1. Though biotechnology will also have a tremendous impact in animal production, this paper will focus exclusively on the applications and implications of the new technology with regard to arable agriculture. Also, the scope of this paper is limited to those nations within the capitalist system.

2. Agricultural production will become increasingly systems oriented. The managment sophistication demanded by new plant varieties will certainly reinforce the trend to on-farm utilization of advances in electronic data evaluation and processing techniques (Geissbuhler et al, 1982:505). As varietal sensitivity or responsiveness to inputs and environmental factors is increased, it becomes ever more important that growing conditions be monitored closely. A variety of crop or function specific (e.g., integrated pest management) computer programs have already been developed by the USDA and private firms.

3. The report is the product of a meeting held in June 1982 at the Winrock Conference Center. The fifteen participants in the Winrock meeting included Denis Prager (OSTP), John Pino (Rockefeller Foundation), Judith Lyman (Rockefeller Foundation), Winslow Biggs (Carnegie Institution), Irwin Feller (Institute for Policy Research and Evaluation), Ralph Hardy (DuPont), John Marvel (Monsanto), Representative George Brown (D-California), Perry Adkisson (Texas A+M University), James Bonnen (Michigan State University), James Kendrick (University of California, Berkeley), Lowell Lewis (University of California, Berkeley), James Martin (University of Arkansas), Terry Kinney, Jr. (USDA-ARS), Peter van Schaik (USDA).

4. Certain provisos need to be made on this point. Particular companies deeply dependent on single crops have engaged in extensive collection work. United Fruit is thought to hold as much as two thirds of the world's banana germplasm (Mooney, 1979) and such companies as Campbells and Heinz have comprehensive tomato germ plasm inventories. Moreover, pharmaceutical companies have been very active in medicinal plant collection and such activities may also become a component of the strategies of their newly acquired seed companies.

5. For information contact the Special Commission on the Corporate Control of Academic Science, c/o The Center for Study of Responsive Law, P.O. Box 19367, Washington, D.C., 20036, (202) 387-8034.

6. For information contact The Committee for Responsible Genetics, P.O. Box 759, Cambridge, MA, 02238.

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NOD 13

BIOTECHNOLOGY -- A BLESSING FOR THE LESS DEVELOPED NATIONS?

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BIOTECHNOLOGY -- A BLESSING FOR THE LESS DEVELOPED NATIONS?

Introduction

In the last two years biotechnology has been heralded by the capitalist press as offering the possibility of fulfilling the world's nutritional (Tamarkin 1981) and medical (Sojka 1981) needs. Biotechnology is the newest technology touted as a solution to the world's agricultural problems (for the most recent iteration of this theme see Swaminathan 1982). Already the United States Agency for International Development has convened a workshop to "assess the potential impact of the new biology" (United States Agency for International Development 1982). Clearly this technology can be expected to affect the less developed countries (LDCs) potentially deepening their dependence on the developed countries. This note outlines some of the current trajectories of biotechnological innovation and their implications. It should be mentioned from the outset that this technology has the potential to accomplish "miracles" but under capitalism could also create disasters for many workers and peasants.

Biotechnology is an entire set of technologies that were developed in the decade of the 1970s as a result of advances in the biological sciences. These include recombinant DNA, immobilized cells and enzymes, cellular fusion, hybridomas, monoclonal antibodies, and cloning among others. These new biotechnologies in combination with older sciences such as plant breeding and fermentation engineering allow the manipulation of biological processes so as to make cells into living factories producing commercial products. In addition, new techniques make possible the rapid multiplication of genetic material, cutting the

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periods necessary to breed new varieties drastically (Meredith 1982). In theory any product based on biological processes can be produced by means of genetically engineered organisms. Of course, for these products to become commercialized they must be less expensive than similar ones produced by traditional methods. The implications for food processing, agriculture, and pharmaceuticals are unmistakable. Thus, a recent report by The Chicago Group Inc. (1981) (which cost $1500 per copy) predicts that agriculture will be heavily impacted by biotechnology by the year 2000. Biotechnologies will affect a wide range of basic consumer products such as food, clothing, energy, and medicine (Kenney 1982).

Biotechnology and the Third World

Biotechnology has the potential to decrease the costs of many goods, especially food and medicine. As mentioned earlier proponents assert that this will improve nutritional and health standards in the LDCs. An examination of the effects of an earlier, less powerful biotechnology, plant breeding, highlight the dubiousness of this proposition (Perelman 1977; George 1977). The epitome of plant breeding success, the Green Revolution, not only made India a nearly self-sufficient grain producer but also led to a massive displacement of peasants accompanied with great hardship and suffering (1) (for a prescient analysis of the Green Revolution see Cleaver 1972 in MR). But as noted by observers (Perelman 1977; Griffin 1974) the Green Revolution only led to "big gains in little areas" (Griffin 1974:10). This was due to the fact that the new hybrid varieties required fertilization, irrigation, and inorganic pesticides. The thrust of the new biotechnologies has been; to develop plant varieties that are stress tolerant, to develop various methods of

inducing nitrogen fixation to reduce fertilizer costs, increase the speed and efficiency of plant breeding, and to produce seeds that require a package of inputs to be viable. The important stress tolerances being engineered for are herbicides, saline conditions, drought, and aluminum (aluminum is a major problem in tropical soils). The most ominous of these goals, for peasants and small farmers in capitalist countries, are those of aluminum, saline, and drought tolerance as they could convert farmland currently unproductive for Green Revolution seeds into areas eminently suited to large-scale capitalist farming (2). Whereas earlier the poor were driven from good land, the new biotechnologies will be able to complete the process of destroying the noncapitalist farmer and small farmer by removing them from the "marginal land" (3).

A striking example of another impact of biotechnology is the world sweetener industry. Sugar, which is largely produced in less developed countries, is increasingly being replaced by a sweetener, high fructose corn syrup (HFCS) produced from corn through the use of recently developed biological technique of immobilizing enzymes. HFCS factories are very capital intensive operating continuous flow processes running 365 days per year, 24 hours a day (4). The volatility of the sugar market and the U.S. import quotas are combining to ensure that HFCS decreases sugar's share of the industrial sweetener market(5). The outcome of the development of this new product has been the erosion of sugar sales and the driving of inefficient under-capitalized sugar producers from the market. This will result in the demise of small sugar producing countries such as Zimbabwe, Sudan, Tanzania, and Zambia and small cane farmers throughout the world. The sugar producers that wish to continue to compete will be forced to mechanize production thereby leading to the elimination of rural laborers. The final outcome of this already occurring process could be the near total elimination of sugar as an industrial sweetener and the demise of the vast bulk of the world's producers, most of whom are located in the LDCs. What has occurred in sugar is being considered for other tropical crops such as opiates, African pyrethrum, and in all probability, many more. The corporate successes in corn syrup are an important incentive to pursue production innovations in other major and minor agricultural commodities.

As with so many other technologies biotechnology will, under the capitalist system, be used to benefit capitalists. If there is an incidental benefit to labor or consumers so much the better. The bulk of plant breeding and biotechnology research is done in non-profit public institutions which in theory are committed to research and development for the social good. The new biotechnologies developed in universities are now being commercialized by private companies which are constituted solely to create profit. The development of new varieties formerly an area of public involvement is being transferred to private corporations which will then control the entire breeding process (Kloppenburg 1982). For example, private capital directs much of this research towards producing hybrid seeds that are not reproductively stable, thereby forcing farmers to purchase seeds annually. In fact, Pioneer and other seed companies are engaged in research to discover methods of hybridizing crops that currently are not physiologically amenable to hybridization. Once a farmer starts to purchase these seeds and abandons traditional seed he will become dependent upon purchased

seeds thus ensuring his integration into the commodity economy. This can be very dangerous for a nation if the seeds are imported. The planting of these imported seeds displaces traditional varieties, this can lead to a loss of genetic diversity and increased crop vulnerability to pests (Fowler 1980).

The obvious importance of biotechnology for production has prompted major efforts in biotechnological research in all developed countries, especially the U.S., France, and Japan. Both France and Japan consider biotechnology as a potential "locomotive" technology to pull their economies out of stagnation. The position of the LDCs is not being considered and may not be enhanced by this technology. It is quite likely that many of the biotechnologically produced products will displace the traditional products that LDCs export.

The "benefits" of biotechnology to the LDCs will probably be in the form of purchasing bioengineered products or the installation by transnational capital of branch factories that take advantage of cheap feedstocks located in the LDCs (Ballimore 1982). There is also a possiblity that certain LDCs could, by virtue of their longer growing seasons, abundant rainfall and relatively open land areas, become important producers. But the mental labor which will be the key to the securing of monopoly profits will in all likelihood remain in the developed countries, though the locus of innovation may shift from the U.S. to Japan.

A frequently mentioned alternative is the possibility that the LDCs could begin indigenous high technology research. There are a variety of problems with this option. The first is the lack of trained manpower to form a critical mass of researchers, though in countries such as India this may not be an insoluble problem. Second, the actual production requirements such as sophisticated machines and biological supplies make proximity to specialty suppliers of crucial materials important. Even in the U.S., the bulk of the high technology R and D is confined to Massachusetts and California. Such things as constant electric supplies, excellent transportation facilities and reservoirs of trained labor power are crucial. Finally any research effort would require a major, long term commitment of funds to create a large enough research establishment to allow synergistic effects to occur.

In India there is already a joint project underway between Indian and German universities to cell culture rare medicinal plants (Chadha 1982). India is proud of this arrangement, yet the outcome of the project may be that the Germans can take the cell cultures back to Germany and produce the active medicinal ingredients through fermentation processes (though certain technical obstacles remain to a total dispensing with the actual plant) (Sahai 1982). A product unique to India would then have been appropriated by German capital. This would be a very high price to pay to learn tissue culture techniques. Biotechnology has many potential implications but the boon to the Third World that the capitalist press currently proclaims, could simultaneously result in an even greater subjugation to transnational capital.

Third World Alternatives

The predicament of developing countries is severe, as the new technologies give transnational capital enormous production advantages. Yet there appear to be certain paths for developing countries to better their bargaining positions. The first concerns the fact that the tropical countries with their enormous plant variety are the world's largest reservoir of genetic resources. This patrimony need not be needlessly given away to the countless companies searching for new varieties containing new breeding possibilities. Neither is it necessary to allow national capitalists to appropriate these resources for their private gain. Further, "gifts" in the form of aid from foreign governments and companies must be examined to understand their full implications and thereby prevent potential losses. For example CIMMYT, the international corn research institute based in Mexico, has allowed the American seed company, Pioneer, to retain a copy of all of its corn genetic material in return for which Pioneer will grow out CIMMYT's varieties (Diversity 1982). The reason CIMMYT is allowing Pioneer to grow out the seeds is that all seeds need to be germinated and reproduced periodically to remain viable -- an expensive process that CIMMYT could not afford. The result is corporate acquisition at extremely low cost of an invaluable resource which had been assembled through government and charitable contributions.

The LDCs must develop the expertise in biotechnology to the point of at least being capable of duplicating products of Western technology. This would be especially valuable with regard to agricultural materials such as seeds. Certainly under no conditions should plant patenting and other legal measures be adopted as these essentially serve the purpose of strengthening capitalism in agriculture. The adoption of international seed legislation will only serve to further the penetration of transnational capital into the agricultural sector resulting in even greater dependence on the part of LDCs. Research should immediately commence in LDCs upon the application of biotechnological techniques to increase the efficiency of the use of sugar as a feedstock, for example the Brazilian ethanol project. This has great promise as sugar cane is a much more efficient converter of sunlight to sugar than corn and the potential for productive advances is great. The developed countries produce little sugar (except in the form of beets) and cannot be expected to pursue research into the uses of sugar cane.

To even attempt to develop efficiently and begin to actually shape the impacts of the new biotechnologies, the LDCs must develop social controls over technology in general. Controls are the only method by which all of the people of the country will be able to share in the benefits of these new technologies. The other alternative is to have the inefficient small national capitals make arrangements with transnational capital but these arrangements would probably run counter to the greater national interest. As with any other technology biotechnology has the potential to improve life, but under capitalism technological advances will be used to further control over farmers and

workers. Biotechnologies offer the possibility of resolving many health and nutritional problems throughout the world. The requirement that capitalists make profit will frustrate and pervert this potentiality. If more profit can be made supplying the upper classes with more meat then biotechnology and its bounty will be applied to that purpose. As Marx wrote over 100 years ago; "Demand also exists for the individual who has no money, but his demand is a mere creature of the imagination which has no effect ... and which thus remains unreal and without object" (Marx 1964:192). Under no condition can biotechnology be seen as a neutral technology — only through struggle can workers, farmers, and consumers control the course of biotechnology.

NOTES

1. The Green Revolution was initially a Rockefeller Foundation project touted as a method by which to produce enough food to feed India. Wheat replaced other more traditional crops such as millet and sorghum. The effects of government subsidies to wheat farmers and the massive production increases were two-fold; on one hand, prices for grains dropped slightly, hurting the small unsubsidized traditional farmer, while, on the other hand, the value of land for growing the new varieties increased. The end result was that millions of people were driven into the cities or became landless laborers. Production had increased, but the landless rural laborers or urban unemployed were unable to purchase the necessities of life (Perelman 1977).

2. Quite clearly these technologies offer enormous potential for all countries but in a socialist country these potentialities could be realized. The social catastrophe that occurred in India in the Green Revolution or in Iran with the Shah's White Revolution could be avoided. For example, Cuba mechanized sugar cane production, but not at the cost of thousands of unemployed rather it moved the liberated workers too much more humane work. Any recommendations given for Third World countries in this paper can only be considered as stop gap measures, only the establishment of socialism can lead to an effective realization of these technologies.

3. The International Plant Research Institute, a private company, is attempting to genetically engineer plants that are saline and aluminum tolerant (Dodge 1982). Drought resistance is being explored by Dr. Ray Valentine of Calgene, a company partially owned by Allied Chemical (Genetic Engineering News 1981:16). Development

of nitrogen fixing plant varieties though receiving much media attention appears to be farther in the future (Walsh 1981). It should be emphasized that these products are not yet in existence, but the world's largest corporations are spending hundreds of millions of dollars to make them a reality and the process of discovery is accelerating.

4. Fructose is a sugar produced by the use of enzymes which decompose corn starch, a long molecule of connected sugars, into its constituent sugars. The cost of corn syrup is reduced because the marketable by-products of the process are animal feed, corn meal, and corn oil (Keim 1978).

5. For example American per capita yearly sugar consumption decreased from 1979 to 1980 from 91 to 87 pounds, in the same period HFCS consumption increased from 15.4 to 19 pounds (Honer 1981). By 1987 yearly sugar consumption per capita is expected to have dropped to 67 pounds, whereas HFCS will have increased to 30 pounds (Hannigan 1982). Some authorities believe that by the 1990s HFCS will have replaced sugar as the world's most important sweetener (Hannigan 1982; Keim 1978).

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10C

GENETIC ENGINEERING AND AGRICULTURE: SOCIOECONOMIC ASPECTS OF BIOTECHNOLOGY R&D IN DEVELOPED AND DEVELOPING COUNTRIES

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This paper is a brief summary of research conducted by a team at Cornell University and explores the socioeconomic context of the emergence of genetic engineering in agriculture. Principal emphasis is placed on the structure of the biotechnology research industry and on the organization of public and private agricultural research in the U.S.A. Preliminary observations are also provided on the impacts of biotechnologies in developing countries. The results suggest that biotechnology has led to increased concentration and integration within the agricultural inputs industry and to pressures for dramatic changes in the structure and functioning of the public agricultural research system. It is pointed out that while biotechnologies promise to lead to major improvements in agriculture and industry in low-income countries, there are major reasons for concern about the impacts of these new technologies on developing nations.

INTRODUCTION

The past 30 years of basic research in molecular biology and related disciplines have culminated in a recent corporate rush to exploit commercially a variety of procedures and processes popularly called biotechnology (BT). Both large multinationals and small venture capital firms have already entered or are entering the field. Although BT potentially has applications in all sectors of the economy where organic chemicals are extensively used, this paper will discuss their current status in agriculture only. We will omit other routinized and traditional technologies (e.g., traditional plant breeding) because such technologies, though indispensable, are revolutionary only in combination with the new BT.

BT applications will become increasingly influential in agricultural production. This paper will also examine BT's influence on the major institutions related to agriculture: the land-grant universities and agricultural input companies. Though the focus of the paper is largely on the U.S., the potential impact of BT on the less developed countries is also examined.

It should be emphasized, however, that BT is not being developed only for agricultural applications. On the contrary, the most important current research is in pharmaceutical and chemical processes, although spin-offs of these into agriculture along with research conducted specifically for agricultural applications will be increasingly important. BT for agriculture is being explored by companies of all types, many of which are not traditional agribusiness firms. This technology could even make farming as practiced today obsolete through the hydroponic cultivation of vegetables and the development of single cell protein cultures which could eventually replace meat or soybeans as a cattle feed. BT may make agriculture more productive by making agriculture, in effect, a branch of nonfarm industry. More importantly, the logic of the development of these new production processes will not be determined by farmers and, perhaps, may even exclude the smaller agribusiness firms. The determining influence will no doubt be the large multinational corporations (MNCs). These firms will be in the best position to control the allocation of capital to BT research and to the ongoing and future production of BT substances. For the foreseeable future, the course of BT development will be largely shaped by these firms' (and, as we will see below, their venture capital firm partners' and seed company subsidiaries')industrial and marketing strategies.

THE STRUCTURE OF THE BIOTECHNOLOGY RESEARCH INDUSTRY

BT research companies can be divided into two major groups. The first are those that do only BT research and which are typically small firms with less than 300 employees; were recently founded--usually in the last four years--by venture capitalists; and have one or more senior researchers from a major university. The other type of company is typically a Fortune 500 firm; produces many products, including agricultural inputs; and believes that the company must have a broad presence in the BT field. The interrelationships between these two types of companies are quite complex. The small companies depend upon the larger ones for financing, and, in turn, the larger ones, due to institutional constraints, find the small ones very useful for generating research breakthroughs. Whether this symbiotic relationship will continue is unpredictable, since there is obvious potential, already partially realized, for the large companies to acquire the smaller ones.

The Venture Capital Firm Sector

The most prominent venture capital companies engaged in agricultural research applications are Agrigenetics, the International Plant Research Institute (IPRI), DNA Plant Technologies, Advanced Genetics Sciences Ltd., Molecular Genetics, and Cetus (as well as Genetic Engineering Co. for animal applications). The reason that "venture capital" is so crucial in private BT R&D is the relatively high costs of starting a laboratory. Estimates for starting a small laboratory with about 12 scientists and associated support staff are about $6-7 million. The "critical mass" necessary to establish a viable firm is estimated to be about 25 Ph.D.s and would require $10-12 million of investment capital (1). Scientists obviously do not have this amount of capital and therefore require outside investors. Consequently, the substantial start-up costs of BT R&D ensure that only those persons or firms able to provide substantial amounts of capital can enter the field. Claims that these companies are small independent entrepreneurs must therefore be tempered by the fact that venture capitalist investors are usually persons with large amounts of investable capital. In many cases, a major share of the small venture capital firm is owned by one of the large Fortune 500 firms. For example, Agrigenetics has received investment from the Ford and Rothschild families. Venture capital firm survival depends upon outside support, but precise information regarding the levels of support is proprietary and largely unavailable. A summary of basic data on certain of these firms is given in Table 1.

Agrochemical and Seed Firms

The list of companies with major investments in BT reads like a compendium of the leaders in the agrochemicals field: Allied, American Cyanamid, Chevron, Ciba-Geigy, Dow Chemical, DuPont, Eli Lilly, Monsanto, Pfizer, Sandoz, and Occidental Petroleum. The petrochemical and pharmaceutical industries have long had considerable agricultural interests via the markets for fertilizers, pesticides, and herbicides. Worldwide sales for the latter two product groups alone totaled $11.5

billion in 1980. However, a recent development in the inputs industry has been the steady acquisition of seed companies by these multinational giants (see Table 2).

Such acquisitions were initially independent of considerations relating to bioengineering, though a few far-sighted corporate planners may have perceived the potentials of the new technology. The agrochemical and seed industries have always had close relations. Seedsmen, with their more valuable crops, use fertilizers, pesticides, and fungicides in the production process with greater intensity than does the average farmer. Moreover, fungicides, sterilants, and disinfectants are standard components of seed processing. Particular types of fertilizers and chemicals are crop- and even variety-specific in terms of compatibility. Chemicals have been seen as solutions to problems that were regarded as insoluble by plant breeders. For example, growth regulators have been developed for purposes such as the stimulation of latex flow, and other chemicals function as pollen sterilants (2).

Over the decade of the 1970s, a number of factors have combined to make full integration of the inputs industry logical, profitable, and even necessary. A principal vector of change was passage of the Plant Varieties Protection Act (PVPA) in 1970. Galvanized by the example of hybrid corn, seed companies had long been pushing for institutionalization of "breeders rights," as had been achieved in Europe in 1961. Passage of the PVPA gave patent-like protection to newly developed plant varieties. This raised the opportunity of attaining handsome profits on the order of the 26.7 percent return to equity that Pioneer had been able to achieve on the basis of its naturally protected hybrid corn lines (3). A second factor generating interest in seed company acquisition was the rapid rise in grain prices early in the last decade and the accompanying anticipation of prolonged world food shortages. The prospective combination of enlarged demand and healthy profits from proprietary plant varieties was undoubtedly very enticing.

While many purchases of seed companies had already been made for these reasons, the rapid growth of the BT movement after 1976 reinforced the acquisition trend. BT introduced the possibility of vastly more efficient breeding methods in the short run and fully engineered plants in the long run. The new technology has ramifications for the entire range of agricultural products manufactured by the agrochemical corporations. Not only does BT promise improved chemical products and more efficient production methods (biorational control, production of chemicals through fermentation processes, nitrogen-fixing bacteria, growth regulators, etc.), it also holds out the possibility of designing plants in such a way that they are complemented by selected chemicals or organisms.

The broad range of areas over which BT is relevant in agriculture, and its potentially enormous impact, force the large companies to hedge their bets by pursuing areas which may in fact prove damaging to current markets. There will be vicious competition as new bioengineered products come on line. Thus, research into nitrogen-fixing microorganisms will continue despite the fact that substantial achievements in this area could devastate fertilizer sales. Similarly, biologic pest control measures are being investigated along with more traditional chemical measures. The outcome of any particular line of research is highly uncertain at present. Complicating matters is what is perceived by the chemical industry as a highly restrictive and unstable regulatory environment. While initiated by the PVPA and the worldwide food situation, integration within the agricultural inputs industry is to be understood as a movement toward diversity and flexibility through investment in a group of industries with high synergistic potential in research, marketing, and distribution.

Concerns have been raised as to the effect of acquisitions by the large multinationals on the structure of the seed industry itself. Concentration in the seed industry is a difficult issue to address, partly because little market information is available, but moreso because of crop differences. In hybrid corn, which constitutes about a quarter of U.S. seed sales, Pioneer has a clear lead with about 35 percent of the market. DeKalb follows with 12 percent. Funk (Ciba-Geigy), Northrup King (Sandoz), Trojan (Pfizer), PAG (Cargill), and Golden Harvest together have 17 percent of the market, and the residual is accounted for by 200 small companies servicing localized areas. The situation is quite variable with regard to all other crops. Pioneer (10 percent) and DeKalb (25 percent) lead in sorghum, but market shares are more or less evenly or geographically distributed. Significantly, for those important crops for which it has not been possible to develop hybrids (wheat, cotton, soybeans), farmers themselves produce and market a large proportion of seeds.

The seed industry is highly competitive, and farmers tend not to show brand loyalty, but rather follow yield potential in choosing seed. Any introduction offering significantly higher yields than current offerings can be expected to alter industry structure radically. Pioneer has established and maintained its position in seed corn with an extensive and sophisticated research program. R&D at Pioneer has increased at 17.5 percent annually since 1975. Recognizing the challenge of BT, their new Microbial Genetics Division was to become operational in 1982. The company already markets several products relating to biological nitrogen fixation. While DeKalb has recently increased its emphasis on R&D and has a small investment in Bethesda Research Laboratory, its market share has been slipping. This may have been a factor in convincing DeKalb to join in a research venture with Pfizer Genetics. Pioneer and DeKalb will certainly face stiff competition in the seed corn market once BT matures sufficiently to allow efficient selection for breeding and, much later, should fully engineered plants become a reality. Principal competitors should be the second tier of companies with large parent firms behind them. Such companies can be expected to gain market share. Unable to compete with the R&D expenditures of the "deep pocket" multinationals and the majors, the small companies will either disappear or, as is more likely, be absorbed by larger firms desiring entry.

Critical to the commercialization of BT in agriculture is a firm's plant breeding capacity. This the large petrochemicals and pharmaceuticals have achieved via their acquisition of seed companies. For example, the Joseph Harris Seed Company in 1979 provided Celanese with the Carl L. Warren Laboratory and a cadre of 30 experienced researchers. Seed companies, and by extension their multinational parents, are capable of setting their own breeding agendas according to their own criteria.

The role of PVPA in sanctioning and encouraging private breeding can hardly be overestimated. Prior to the passage of the PVPA, public varieties dominated pure-line crops, and private companies did little more than see to production and marketing of seed. Unprotected varieties carried very low profit margins, for if the price went too high the farmer simply saved and replanted from his crop. Seed prices, even of superior varieties, could therefore never deviate far from bulk grain prices. Moreover, there was nothing to stop any grower from reproducing and selling an unprotected variety. The solution to both problems is, of course, hybridization. But hybridization has proven elusive in some of the most potentially lucrative crops--hence the PVPA. Proponents of the PVPA argued that its passage would stimulate private breeding; this it has unquestionably done. Private companies have flooded the Plant Variety Protection Office with applications. Between 1970 and 1980, 632 certificates of protection were issued. Of these only 13 percent were issued to public breeders (4). Research has centered on wheat, soybeans, and cotton. As of May 1980, over 200 certificated were issued for soybeans and 109 and 94 for wheat and corn, respectively. It is quite possible that private companies simply protect every new variety, whether it enters commercial production or not, so that any subsequent use, in the market or as a parent line for a further variety, will generate royalties. Companies have not been shy about protecting their rights under PVPA. Several cases have gone to litigation, though a letter from a seed company lawyer to the farmer in violation is generally sufficient to ensure compliance.

The reasons for corporate expansion into agricultural input markets are obvious: Even in the present world economic slump, farm chemicals and seeds continue to return high profits. For example, in the first half of 1982, Monsanto's agricultural products were the only operation to gain in sales and operating profits (5). Similarly good earnings prospects are true in other agricultural chemical markets, except fertilizers. Finally, Pioneer's impressive profit margins are an extremely powerful inducement to entry into the seed industry. The PVPA.

in providing patent-like protection for plant varieties (with no regulatory delays for approval), has provided a strong incentive for large firms to enter what is presently and will likely continue to be a lucrative industry. Moreover, BT holds forth the promise of developing varieties not suitable for hybridization that are reproductively unstable, which has made the seed industry all the more attractive for large-scale private investment. These factors will no doubt combine to lead to a fundamental transformation of the U.S. seed industry. The predominant firms in this industry will increasingly be subsidiaries of large petrochemical and pharmaceutical MNCs, and the principal features of industrial strategy will be to take advantage of the new opportunities afforded by legal changes and BT breakthroughs and to integrate seed production with existing agrochemical product lines.

THE CHANGING ROLE OF AGRICULTURAL RESEARCH

The potentially determinate relationship between the seed and agricultural production processes which is emerging from BT advances makes control over plant breeding an item of paramount importance. Yet this is the very area in which public agricultural research agencies enjoy a measure of preeminence vis-à-vis private industry. In the U.S., private industry achieved a major precondition for the effacement of public research in 1970 with the passage of the PVPA (the European counterpart of which occurred much earlier). Since that time seed companies have been attempting to redefine the role that is played by the public breeder (6). BT renders the need to circumscribe public breeding activities yet more urgent, for the seed is now the gateway to control over the production process as a whole. Industry would like to see tne activities of the public sector confined exclusively to those areas not attractive to private investment: education and training, the evaluation and development of germplasm, and basic research. Applied research, by which is meant the release of finished commercializeable varieties, is explicitly seen to be the responsibility of the private sector. For example, the USDA's Agricultural Research Service has made disengagement from applied breeding one of its institutional objectives.

Public institutions face declining state and federal aid for plant breeding research. They are finding it increasingly difficult to recruit and retain staff and to keep operating funds at a reasonable level. Several state programs have already shifted their focus from varietal development to germplasm development and population improvement, and a general trend to enhanced cooperation with corporate breeding is evident (7). With some 56 private companies currently constituting the National Council of Commercial Plant Breeders, the land-grant universities (LGUs) are under continuous pressure to abandon those areas of research which can profitably be undertaken by private enterprise. A similar trend can be observed with regard to the international agricultural research centers.

For all its promise, BT is as yet an embryonic technology. The outcome of any one line of research is highly uncertain, and while progress is being made daily there are yet many fundamental problems to be overcome and much research to be undertaken before extensive commercialization of "engineered" products can be realized (8). The concrete imperative of profitability makes absorption of expensive and indeterminate basic research costs by government a desirable option from the corporate point of view. Yet the present structure of the USDA and LGU system is not geared to the efficient pursuit of the new lines of research which advances in biological knowledge have opened up. It is to this constraint that the corporations and their institutional allies have turned.

The Rockefeller Foundation and the White House Office of Science and Technology Policy (OSTP) recently issued a joint report bluntly indicting the USDA for its parochialism, bureaucratic rigidity, regional geopolitics, and inability to identify research areas of critical importance (especially BT). A substantial portion of the problem is attributed to the dispersed and decentralized nature of the Agricultural Research Service and to the lack of control over block grants which support research in the LGSs and associated state agricultural experiment stations. The report recommends a restructuring of the American agricultural research system. The principal features of this realignment would be the consolidation of ARS stations and programs, a concentration on basic "cutting-edge" research, and the expansion of the currently modest competitive grants program (9). Implementation of the recommendations could well result in a transformed LGU system that is increasingly replaced by a structure based on a "project-funding" model of highly centralized research facilities in a few locations. The Rockefeller/OSTP report (10) asserted that

> [p]rivate sector expertise should be fully utilized in efforts by the public sector to identify future research needs, estimate future demand for scientific and technical manpower, and define appropriate, complementary roles and responsibilities for the various sectors and institutions involved in science for agriculture. Mechanisms should be developed for strengthening the linkages between the findings of basic and applied research performed in the public sector and their development and commercialization in industry.

Stimulated by the revolutionary potential of BT, the very role of the public research system in the U.S. (and perhaps in the international agricultural research centers) is being transformed.

Perhaps one of the more fundamental impacts of BT on university-based agricultural research will occur outside of the LGU system. What, in fact, prompted the Rockefeller/OSTP conference was the perception that the public agricultural research facilities of the U.S. were lagging in the exploration of BT research. It is generally recognized that the LGUs are not prominent among the leading universities in the basic sciences of molecular and cellular biology. Accordingly, many firms with BT investments related to agriculture (e.g., Monsanto) are directing their investments outside the public agricultural research system and to prestigious private, non-LGU universities. If the structural reforms advocated by the Rockefeller/OSTP group are not implemented, the basic thrust of cutting-edge BT research may continue to shift away from the LGSs and toward prestigious private universities such as Harvard University, Rockefeller University, and MIT.

POTENTIAL EFFECTS OF BIOTECHNOLOGIES ON LESS DEVELOPED COUNTRIES

As emphasized earlier, the structure of the agricultural inputs industries in developed countries is undergoing increased concentration and centralization under the aegis of large petrochemical and pharmaceutical MNCs. However, it is important to recognize that BT is a global technology, and the Third World is a vast potential market. There have been several promising discussions of high priority applications of BT to agriculture and nonfarm industry in low-income countries (10). There is agreement that BT's potentials for agricultural and industrial productivity improvements and for improving living standards are as great or greater in Third World countries than they are in the developed regions of the globe.

Amidst the otherwise promising potentials of BT in low-income countries, one must also recognize that these improvements in agriculture and industry will be accompanied by strains and dislocations, both economic and social. For example, the development of the techniques of BT has heightened conflicts between industrial and less developed countries over access to and control over germplasm resources. BT processes threaten to undermine export markets for raw materials (e.g., derivatives of the opium poppy and pyrethreums, sugar). Finally, the tremendous expense, technological sophistication, and proprietary nature of BT may, at least for some time, reinforce the technical dependence of Third World countries on industrial ones.

We will comment first on the debate over genetic diversity which has become prominent in the media recently. It is widely recognized that the successful transfer of high-yielding commercial crop varieties to Third World agriculturalists comes at a significant cost: High-yielding varieties displace traditional varieties and reinforce monocultural practices, thereby resulting in the essentially irreversible loss of the genetic information contained in traditional varieties. The result is a "genetic tragedy of the commons." Seed companies face contradictory firm- and industry-level imperatives: Individual seed companies must extend their marketing network to all corners of the globe, but the aggregate consequence of individual firms' strategies is to destroy the germplasm resources that the industry requires to develop new, more productive varieties. Although many seed companies have germplasm banks, it has become increasingly apparent that the tutions, both national and international. Contrary to many popularized arguments, seed companies are not intent on destroying germplasm resources; though individual firms' strategies to expand sales do exacerbate the genetic tragedy of the commons, seed companies and their trade associations have, in fact, been active advocates of greatly increased public national and international funding of germplasm collections.

There has been an increasing awareness among low-income countries of the value of their genetic resources and of the asymmetry of the flows of novel germplasm between the developed and underdeveloped countries. U.S. and European seed companies depend upon the genetic resources of low-income countries and hope to be able to continue to "import" useful genetic material from these countries without "interference." However, commercial varieties that are sold to agriculturalists in low-income countries are proprietary and increasingly subject to international legal strictures that protect "breeders' rights." For example, the incorporation of an Ethiopian barley gene containing striped rust resistance into U.S. barley varieties has saved U.S. farmers an estimated $150 million annually (11). Ethiopia, however, has not shared in the benefits from striped rust resistance. Accordingly, an increasing number of developing countries are now forbidding the export of germplasm because of its economic value. This trend will certainly accelerate as plant patenting legislation and BTs are used to incorporate genetic information into new seeds. Developing countries will increasingly find themselves buying from foreign firms the proprietary seeds which contain genetic information originating in their own countries.

A second set of dislocating effects of BT in developing countries will likely occur as a result of tissue culture technologies which allow the production of commercially valuable secondary metabolites by industrial fermentation processes. For example, Plant Science Ltd. (England) is examining the commercial possibilities of producing the active ingredients of the opium poppy, digitalis, cinchona, and ginseng by fermentation. Other companies are already examining comparable processes for pyrethrums. Opium, cinchona, and pyrethrums are topical crops, and are produced in tropical developing countries. The supplanting of these crops by tissue culture-derived materials could adversely affect several developing countries. Parallel innovations in the production of substitutes for sugar have already contributed to a virtual depression in the world sugar market. Yet another tropical commodity that may be amenable to biotechnological manipulation is palm oil, which may be convertible to cocoa oil through the use of genetically engineered bacteria. The unfortunate implication for developing countries is that BT innovations in the production of industrial chemicals and pharmaceuticals heretofore derived from agricultural raw materials could undermine developing countries' export markets before BT's benefits will be realized in agriculture and nonfarm industry.

At the same time, it is important to emphasize that BT offers tremendous potential benefits to tropical Third World countries with their abundance of water and year-around sunshine. For example, Brazil's program for converting sugar cane (and other feedstocks) into ethanol could be greatly aided by the development of more efficient bacteria for fermentation. Plants genetically engineered for stress tolerance could transform marginal agroecological zones into productive agricultural land, thereby providing increased food supplies for the malnourished. Of course, these benefits will be greater to the degree that the R&D is performed by developing country scientists and the inputs are manufactured by developing country enterprises. Unfortunately, the prognosis for Third World autonomy in the setting of R&D priorities and the manufacturing of BT-related commodities is gloomy. There is a certain irony in the fact that Third World agricultural (and industrial) R&D capacity had begun to approach parity with that of the developed industrial countries in the mid-1970s, only to have these R&D disparities sharply widen again over the past decade due to BT and other high-technology breakthroughs. We feel that foreign assistance efforts of the U.S. and other developed countries should begin to place a high priority on the transfer of BT R&D capacity to developing countries so that they can enjoy the full benefits of this pathbreaking set of technologies.

CONCLUSION

BT has sparked, and been sparked by, international R&D competition among both large and small firms, competition that over the next 20 years will fundamentally transform agricultural production. While the broad outlines of this transformation are becoming clearer, man of the specific forces that will affect agriculture will be the direct or indirect results of industrial strategies among venture capital/MNC/seed company "triads" as these strategies evolve over the next several years.

Most observers of agricultural BT have tended to focus their attention on research breakthroughs occurring in the venture capital sector of the BT industry. These research breakthroughs will undoubtedly have a general determinate influence on change in agricultural organization and the structure of agriculturally-related institutions. However, we feel that one can overexaggerate the role of the venture capital sector. The major force that will shape the commercialization of agricultural BT is the articulation of these technologies with the product lines and marketing strategies of seed companies and their multinational parent enterprises (with, the exception of Pioneer). The seed is the biological and commercial nexus of most efforts to genetically engineer plants. Any breakthrough is for nought commercially if the seed (and related commodities such as innoculants) cannot be marketed to the farmer. The heightened pace of petrochemical and pharmaceutical company acquisitions of seed companies over the past decade has been, in part, a reflection of this [illegible] opportunities it affords. More specifically, seed companies provide agrochemical firms with the in-place marketing network (and sometimes the R&D infrastructure) to make genetic and cellular manipulative technologies a commercial reality. The genetic material represented in seeds will no doubt become increasingly amenable to "reprogramming" to optimize a specific bundle of biological and chemical inputs. This optimization will allow an input firm to sell a complete agricultural "package" to the farmer. In theory, both the farmer and the input firm should benefit—the farmer achieving higher yields at reduced costs, and the company securing a higher sales volume from sale of the package and higher profit rates by capturing part of the yield increase in the price of the seed.

The thrust of technological and socioeconomic change in agriculture will be decreasingly shaped by the research priorities of public agricultural research institutions, in our view. This will not necessarily be because these public institutions lack the research capability. Instead, plant breeding has become privately profitable and attractive for large-scale capital investments, and the nature of "finished varieties" will be shaped primarily in private rather than public laboratories. Correspondingly, public plant breeding is being increasingly relegated to "basic" (noncommercializeable) research and to the collection and evaluation of germplasm for private breeders. The demise of public varietal development is by no means complete. But even if private firms are not entirely successful in implementing their image of the desirable division of labor between public and private breeding, the high capital intensity of BT-related plant breeding will render public breeding technologically antiquated vis-à-vis its more adequately funded counterpart in the private sector. University plant breeding laboratories will probably depend more and more on private research grants from petrochemical-seed enterprises, giving private breeders additional leverage over the content of public breeding research.

While this paper has been largely focused on the socioeconomic transformations induced by BT, it should be apparent that the petrochemical-seed firms are actively positioning themselves for entry into new markets that BT will create in the larger world economy. These world scale markets include (but of course are not limited to) developing countries. Nevertheless, BT R&D is underway on a global scale, and no company can afford to operate only in its home country. Plant variety protection legislation and agreements and germplasm collection are important components of this process and are also being globalized.

BT promises great benefits and significant pitfalls for developing countries and their agriculturalists. On the positive side, improvements in the speed and efficiency of germplasm evaluation and of the techniques for genetic alteration of plants open up vast new avenues for crop improvement. In particular, the ability to breed for stress tolerance will make it possible for new varieties to be adapted to marginal soils, extremes of climate gical conditions. In more favorable agroecological zones, BT innovations in crop improvement can enhance existing efforts at multiple-cropping and prevention of pre- and postharvest losses. Yet biotechnology could have some very negative implications for various agriculturalists. We have discussed the adverse circumstances relating to the asymmetry of germplasm-variety flows, the threats to agricultural export markets, and the reinforcement of Third World technological inferiority in agriculturally-related R&D. BT holds enormous promise for a more productive and efficient agriculture. But it may also lead to an increasingly concentrated and centralized farm system. Will this new agriculture accelerate the demise of the small farmer? Will the current concerns regarding monoculture and genetic diversity be exacerbated? BT has put mankind on the threshhold of a new era in the use of our natural-biological resources. But with this power and potentiality come new responsibilities of ensuring that the benefits do not outweigh the costs.

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Table 1. Agricultural Biotechnology Venture Capital Firms: Principal University-Based Researchers, Financial Linkages, and Areas of Research.*

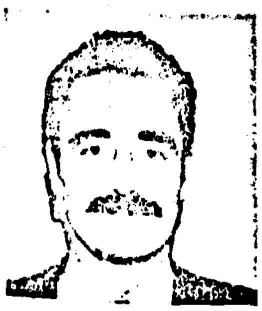
Company	Principal University-Based Researcher and Researcher's University Affiliation	Financial Linkages	Areas of Research
Agrigenetics	Dr. Timothy Hall, Univ. of Wisconsin Dr. John Kemp, Univ. of Wisconsin/USDA	Henry Ford and Rothschild Families Pioneer Group, Claeys-Luck	Seed-related biotechnologies
Advanced Genetics Science	Dr. Lawrence Bogorad, Harvard Univ. Dr. Shepard, Kansas State Univ.	Rohm & Haas	Cloning of disease-resistant potatoes
International Plant Research Institute	Formerly Dr. Martin Apple, Univ. of California, San Francisco	Davy-McKee Corp. Eli Lilly (contract) ARCO, Trans KB	High yielding potatoes, saline-resistant wheat, virus-free cassava
Zeocon Corp.	Dr. Peter Carlson, Michigan State Univ.	Sandoz (formerly Occidental Petroleum)	Soybean and cotton breeding
Calgene	Dr. Raymond Valentine, Univ. of California, Davis (present status unclear)	Allied Chemical (20%)	Plant genetics
Genetic Engineering Co.	Dr. Edwin Adair, Swedish Medical Center, Denver; Dr. Thomas Wagner, Ohio Univ.		Animal genetics
DNA Plant Technology Co.	Dr. William Sharp, Campell Soup Co. Dr. David Evans, Campbell Soup Co.	Campbell Soup (40%), Koppers Co., John Brown & Co., Schroder Bank	Tomatoes, tobacco, forestry products
Molecular Genetics	Dr. Burle Gengenbach, Dr. Ed Green, Dr. Ron Phillips, Dr. Joachim Messing, all of Univ. of Minnesota	American Cyanamid, Smith Kline, U.S. Dept. of Defense	Corn, scours prevention, and nonagricultural applications

*All information is accurate to the best of our knowledge, but it should be kept in mind that the proprietary nature of these firms makes it difficult to keep abreast of the latest data.

Table 2. Multinational Corporations, Product Lines, and Seed Company Subsidiaries.*

Multinational Parent	Primary Products	Seed Subsidiaries
Sandoz (Switz.)	pharmaceuticals	Ladner Beta Seed (Can.) Zaadunie (Neth.) Northrup King (U.S.A.) Rogers Brothers (U.S.A.) National-NK (U.S.A.) Sluis en Groot (Neth.)
Shell (UK/Neth.)	oil, chemicals	International Plant Breeders (UK); Companie General de Semillas (SP); Rothwell Group (UK); Interseeds (Neth.); IPB Japan (Japan); Nickerson P. Gmbh (W. Ger.); Zwaan (Neth. & Bel.) North American Plant Breeders (U.S.A.; with Olin Chemical)
CIBA-Geigy (Switz.)	pharmaceuticals, chemicals	Funk Seeds Intl. (U.S.A.) Stewart (Can.) Louisiana Seeds (U.S.A.) CIBA-Geigy Mexicana (Mex.)
Celanese (U.S.A.)	textiles, chemicals	Celpril (U.S.A.) Moran (U.S.A.) Joseph Harris (U.S.A.) Nugrain
Cargill (U.S.A.)	grain marketer	ACCO (U.S.A.) Dorman (U.S.A.) Kroeker (Can.) PAG (U.S.A.)
Occidental Petroleum (U.S.A.)	oil, petrochemicals	Ring Around Products (U.S.A.) Excel Hybrid (U.S.A.) Missouri (U.S.A.) Moss (U.S.A.)

*These data are presented for illustrative purposes only, and their accuracy and completeness are subject to the same provisos noted in Table 1.



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Computer-Aided Design

Electronics, Comparative Advantage and Development

Raphael Kaplinsky

A UNIDO Study
United Nations Industrial
Development Organization

Frances Pinter (Publishers), London

2 LONG-WAVE CYCLES, ELECTRONICS AND LDCs

In this chapter we will be concerned to describe the fundamental importance of electronics in contemporary economic history. We will also explain why we believe that the diffusion of electronics-related innovations will be associated with changes in the international division of labour in industrial products. This discussion is a necessary prelude to the analysis of the CAD sector that follows, since it illuminates the context in which CAD is diffusing downstream to the manufacturing and allied sectors. It also illustrates how apposite is the choice of this sector as an example of electronics related innovations.

2.1 Long-wave cycles and electronics

Following two post-war decades of sustained and widespread economic growth, the worlds' economies are now, both individually and collectively, in a state of 'crisis'. It began with the LDCs in the early 1960s, spreading to some of the less dynamic DCs (the United Kingdom, the United States and Italy) in the 1970s and now even threatens the sustained growth of stronger economies such as West Germany and Japan. Not only are individual economies facing difficulties, but major multi-national systems of economic and political co-ordination stand on the precipice of disaster. Perhaps the best example of this is to be found in the international banking system which, increasingly reliant on debts incurred by vulnerable economies such as Poland, Zaire and Brazil, is repeatedly forced to co-ordinate rescue operations with both political and economic undertones.

Unlike the previous crisis of the 1930s, which was characterized by depressed demand, recession and stable prices, the current situation is one of stagflation, that is, simultaneous inflation and recession. Two differing explanations of this contemporary crisis are dominant in Western economic thought, namely the Keynesians and the monetarists. The former concentrate on the recessionary aspects of the contemporary situation, aiming to re-stimulate growth through demand expansion and hoping to contain inflation via reduced unit costs arising from scale economies and incomes policies of an explicit or implicit sort. By contrast the monetarists put great

emphasis on the need to combat the inflationary aspects of the contemporary situation, arguing that the expansionary momentum of the Western economic system has been blunted by the ravages of inflation and the obtrusion of the demand-managing state in the sphere of accumulation.

Increasingly, however, a more historical set of explanations has begun to surface, situating contemporary crisis in a broader sweep of history.[1] Building upon a history of economic thought encompassing the writings amongst others of Marx, Schumpeter and a Russian writing in the 1920s called Kondratieff, attention has been placed on so-called long waves of economic activity, often called 'Kondratieff waves'.[2] Basically, the argument is that there are long wave cycles of economic activity and that contemporary stagflation must be seen as part of a downswing of the most recent cycle. While in the past these cycles appear to have had a duration of around fifty years, it is readily acknowledged that there is no justification for any fixed periodicity.

Great difficulties emerge in the measurement of these long-run cycles due to the inadequacy of historical data for almost all economies. Indeed a variety of attempts are currently being made in both European and North American universities attempting to provide flesh to this analytical skeleton. But, as Kleinknecht (1980) in his survey of various long-range theories argues, 'Although proof of long Kondratieff-*swings* thus appears very doubtful, one cannot ignore the fact that the data do reflect long-term fluctuations in the rhythm of growth' (p. 9). In support of this conclusion, Kleinknecht provides a summary of the various attempts made to measure the duration and intensity of these cycles, which is shown in Figure 2.1.[3] He cautions us that 'It must be kept in mind with regard to Chart 1, that the various authors present not only different explanations of long fluctuations, but they also have differing conceptions of the fluctuation patterns themselves' (p. 10).

But whatever the caveats with regard to the precise intensity and periodicity of these cycles, for the purposes of this study it is sufficient to note that there is now a fairly strong consensus that such long-wave cycles do indeed exist, that they have had a periodicity of approximately fifty years, and that – (with the exception of Rostow (1978) and Mandel (1980) – it is generally agreed that we do not yet appear to have reached the low point in the downswing of the most recent cycle.

The recognition of these cycles does not on its own remove the rationale for Keynesian or monetarist responses to stagflation, but it does of necessity place them in a different perspective.

importantly as we shall see, it forces attention to the sphere of accumulation and the significance of technical change. And here the value of the earlier works of Marx and Schumpeter are most apparent.

In this context, Freeman (1978, 1979) and Clark, Freeman and Soete (1980), provide a particularly believable explanation for these long-run cycles. Their argument runs as follows.[4] Economic growth in the West has been fuelled by a supply-side motor, with entrepreneurs pursuing the goal of monopoly profit and achieving these profits through the innovation of new technological developments. Their achievements were reflected in a series of investments by competitors who were attracted by these supraprofits. The result was that competition increased and the monopoly profits were gradually whittled away.

But, as Clark *et al.* point out, even if this should indeed be the motor of economic growth, there is no reason why this in itself should lead to cycles of activity. The *cycles*, they argue, are in part created by inflexibilities, lags and imperfections in the behaviour of

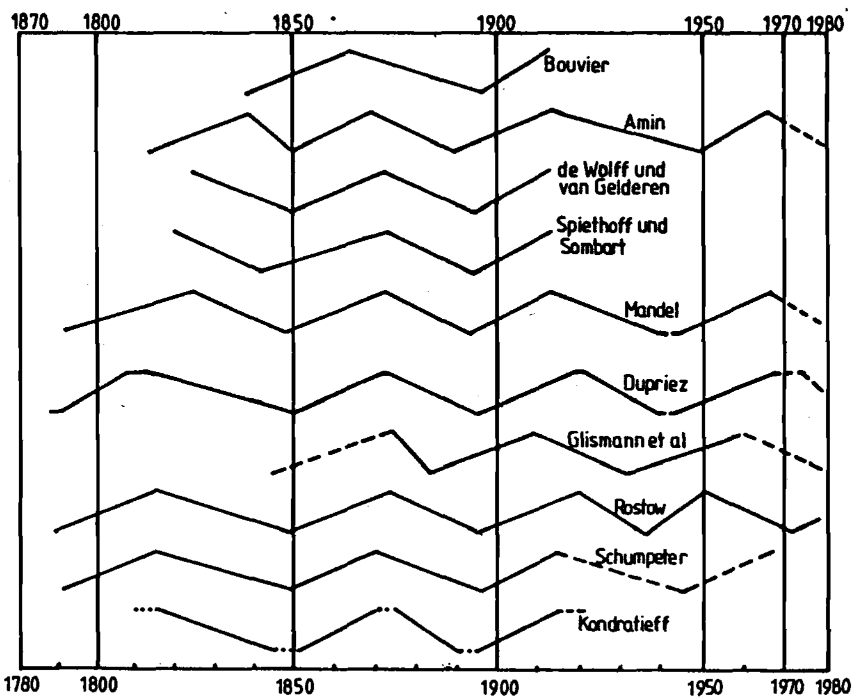

Figure 2.1 Dating of long-term fluctuations by different authors. (Source: Kleinknecht, 1980)

both capitalists and labour, and by the indivisibilities of fixed capital. Yet, despite the existence of these imperfections and indivisibilities, this does not necessarily imply the existence of cycles, since a sufficient number of randomly distributed minicycles should even-out any long-term fluctuations. So, they argue:

> Big wave effects could arise [only] if some of these innovations were very large and with a long time span in their own right (e.g. railways) and/or if some of them were interdependent and interconnected for technological and social reasons. (Clark *et al.*, 1980, p. 25)

Freeman (1977), basing himself on the earlier pioneering work of Konratieff and Schumpeter, argues that over the course of the last 200 years, there have indeed been a series of major, '*heartland technologies*' which have fuelled these long-run cycles ('big-wave effects'). The first of these, beginning in the late eighteenth century was based upon textiles and the diffusion of the steam-engine; the second, with its onset in the mid-nineteenth century, was fuelled by the combined expansion of railroads and the diffusion of steel; the third, with its origins at the turn of the twentieth century, was based upon the internal combustion engine, electricity and the chemical industry; and the fourth, argues Freeman (1977), has been fuelled by electronics technology, beginning with the use of the valve in the 1930s, and proceeding with the invention of the transistor in the late 1940s, the integrated circuit in 1959 and the microprocessor in 1971.

Now in each of these heartland-technology based cycles, there is an 'expansionary' upswing and a 'rationalizing' downswing.

> In the major boom periods [i.e. the upswing] new technological systems tend to generate a great deal of employment, as the form which expansion takes is the installation of completely new capacity and since the technology is still in a relatively fluid state the new factories and plants are often fairly labour-intensive. New small firms may also play an important role among the new entrants and they tend to have a lower than average capital intensity.
>
> However, as the new technology matures [i.e. the downswing] several factors are inter-acting to reduce the employment generated per unit of investment . . . . Economies of scale begin to be important and these work in combination with technical changes associated with increasing standardisation. A process of

concentration tends to occur and competition forces increasing attention to the problem of cost-reducing technical change. (Clark *et al.*, 1980, p. 27)

So, whatever the specific difficulties associated with measuring the intensity and periodicity of the cycles, or the particular analytical motor provided in explanation, we cannot fail to recognize their existence and significance. But there clearly is a danger in being too mechanistic in any such interpretation, for each cycle has its particular characteristics. Thus, accepting (as Freeman and others argue) that electronics is the heartland technology of the contemporary cycle, we should still recognize that there are specific characteristics to it. By so doing, we can attempt to situate the current global crisis referred to in the first paragraphs of this report, as well as to analyse the particular role played by LDCs in the international division of labour in industry. [5] It also will help us, as we shall argue below, in providing a context in which this sectoral study on CAD is to be situated.

The first twenty-five years of post-World War II economic growth reflected a combination of two sets of factors. The first of these was the reconstruction that followed the devastation of war. The second concerned the expansion associated with the introduction of new products based upon the heartland electronics technology. Such products can be divided into four major categories (Freeman, 1981), namely consumer electronics (radio, television, record-players, tape-recorders, etc.), electronic capital goods (radar, computers, communication equipment, process control etc.), electronic components (valves, transistors, integrated circuits, resistors, etc.), and military equipment (radar, missile control systems etc.). In each sub-sector the introduction of new products was associated with rapid expansion of production, employment and trade.

By the end of the 1960s, reconstruction was largely complete, markets had begun to be saturated, [6] and as Mandel (1980) argues, there was also a systematic tendency towards under-consumption. Conjuncturally, the electronic cycle was moving into the downswing as major new product developments had been exhausted and more imitative firms had moved in to the sector, attracted by high profits and the rapid growth of markets. Thus not only were most markets characterized by increasing competition (which took national forms, with Japanese enterprises rapidly coming to dominate the consumer electronics markets and American firms doing well in other sectors), but the power of organized labour had begun to grow after a period of sustained near full employment, and cha[illegible] in [illegible]olog[illegible]ere [illegible]g t[illegible]est[illegible] of [illegible] cap[illegible]

intensive technologies. The consequence was that the 1970s saw a significant decline in the rate of profit in almost all economies (Hill, 1979); growing over-capacity in most major markets such as steel, shipbuilding and cars (OECD, 1979; Mandel, 1980); growing unemployment (Kaplinsky, 1981); inflation; and low/negative rates of economic growth. In the latter period further fuel was added to the flames of stagflation by the increase in energy costs, which reflected technological rigidities as consuming nations were unable to adjust rapidly to the changing relative price of energy. Next to the increase in energy prices, perhaps the most important development for the LDCs in the latter period was the decline in the rate of growth of world trade, which had expanded rapidly when the advanced economies were experiencing rapid economic growth and near-full employment, but fell off rapidly as these conditions no longer pertained.

2.2 LDCs in the context of long-wave cycles [7]

The same post-war period which saw the upswing of the electronics-based cycles also saw the decolonization of much of Asia and Africa and the growth of import substituting industrialization in both these continents and in Latin America. These industrialization strategies were based upon the restriction of imports with the concomitant growth of local production and a growing squeeze on foreign investment. Little attention was given in this period to the possibility of industrializing through the growth of exports since it was recognized that production in LDCs was unlikely to be competitive with DCs. The rationale for industrialization through import substitution was a growth in learning-by-doing and reduced unit costs as scale of production built up to optinal levels. It was only after these hurdles were surmounted that the comparative advantage of cheap labour could allow for competitively priced exports, or so it was believed.

The problem with these strategies was that once the easy early stages of import substitution were exhausted, the rate of economic growth began to slacken. This was in part because, characteristically, the productivity of capital in the intermediate and capital goods sectors was much lower than that in the consumer goods, 'final assembly' sectors. At the same time it became apparent that import substitution was proving to be an 'inefficient' way of conserving foreign exchange, and by the early 1960s many of the LDCs were beginning to experience severe balance of payments problems. Ho[illegible]r by[illegible] mi[illegible]0s [illegible]w p[illegible]men[illegible]as b[illegible]ing[illegible] emerge in the world economy – a number of LDCs had either decided to change, or were induced to change their attitude towards foreign investment. Investment controls were relaxed and favourable tax and duty concessions were introduced to attract foreign investment which would produce for export. In addition favourable incentives were offered to indigenous firms to encourage them to export (Bergsman, 1979).

The results of this shift in policies were remarkable for a selected number of countries, leading to hitherto unheard of levels of growth in both exports and GDP. Korea's manufactured exports, for example, grew at an annual rate of 36 per cent between 1965 and 1975, with its *per capita* GNP growing at 7.3 per cent per annum in the same period. In the early phase these exports of manufactures were of the classic low-technology 'mature' products where LDCs competed on the basis of low wage costs (see Vernon, 1966). But increasingly, the technological gap between some LDCs and DCs began to diminish and LDCs came to be significant exporters of skill-intensive goods and services (see Plesch, 1978; Lall 1979; Katz, 1978, O'Brien, 1981). Despite the fact that only a limited number of countries – ten LDCs, for example, exported 78 per cent of all LDC manufactured exports in 1973 – profited from this extraordinary phase of export-led growth, the demonstration effect was enormous, with an increasing number of LDCs rapidly dismantling import substituting strategies and controls over foreign investment and substituting export-oriented policies, often based upon free trade zones. The international community also responded to their success – noting a growth in the LDC share of world manufacturing value added from 6.9 per cent in 1960 to 8.6 per cent in 1975 (UNIDO, 1980), the UNIDO Lima Declaration called for an LDC share of global output to expand to 25 per cent by AD 2000.

However all this occurred in a period in which, as we have seen, the long wave was in an upswing. Three particular facets of this upswing defined a role for LDCs in the inter-national division of labour. The first was a response by TNCs (initially American and subsequently, but to a lesser extent by Japanese and European competitors) to growing competition in the world market, which, as we have seen, is characteristic of the mature phase of the upswing. One way of cutting costs was for firms to decompose the labour process and have the labour-intensive elements undertaken in export processing zones in low-wage economies.[8] The second aspect of the upswing which defined a role for the LDCs was the very heavy requirement for labour in the heartland technology itself. Manufacture of the silicon chip, when produced in sufficient numbers, was

cheap, with almost insignificant marginal costs – by contrast the packaging of these chips in their plastic containers and the insertion of connecting wires was a costly item, with little difference between marginal and average unit costs. Consequently there was intense pressure to reduce these assembling costs (which were predominantly labour costs) and the logic pushed firms towards using low wage labour in LDCs. And thirdly, the high levels of employment and economic growth in most DCs meant that cheap wage goods – predominantly those with a high labour input[9] – could be imported from LDCs without adding significantly to the levels of unemployment in the DCs.

The confluence of these three sets of related, favourable factors explains the great success in the growth of LDC manufactured exports over the past fifteen years. It also explains why so many LDCs began to institute policies designed to emulate the success of these economies – between 1978 and 1980 for example, the number of free trade zones increased from about 220 to over 350, most of these being in LDCs (Frazier, 1981). But it is precisely in this regard that the relevance of long-wave cycles, and the important role played by the heartland electronics technology, assumes its importance. Each of the three sets of favourable factors that have underlain export-led growth by LDCs is threatened as the current cycle moves into the supra-competitive, rationalizing downswing. Thus the favourable market-entry conditions into DCs for LDC manufactured goods – whether arising from 'runaway' TNC investments or from indigenous LDC firms – has begun to be eroded. Even before the most recent phase when the heartland electronics technology has begun to diffuse downstream in a cost-reducing role (which partly takes the form of displacement of labour by electronics-related innovations), employment in manufacturing sectors in DCs had begun to fall (Kaplinsky, 1981). At the same time the potential role of the services sector in absorbing this labour (Bell, 1974) appears to be threatened by electronics-related innovations (Freeman, 1977). Consequently, as unemployment rates have begun to rise in DCs, so have protectionist barriers, beginning in the most labour-intensive sectors (e.g., garments) and now spreading to other consumer (e.g., cars and television) and intermediate goods (e.g., steel). Secondly, the downstream use of electronics in other sectors has begun to undermine the comparative advantage of LDC firms producing with traditional technology and low-wage labour. And, thirdly, developments within the electronics sector itself, such as automated insertion of integrated circuits onto printed circuit boards, the packaging of the circuits themselves and the reduction of the number of circuits in many products due to the development of more powerful very large scale integration (VLSI), have diminished the requirement for cheap labour.

The burden of the previous discussion, therefore, is that the world economy has, over the past five to ten years, reached a minor turning point, which has fundamental implications for the global location of industry. In the preceding phase there existed a clear opportunity for export-led industrial growth in LDCs. But, now, many of the underlying phenomena that facilitated this type of industrial growth have begun to change. The source of this change has been the move from the expansionary upswing of the electronics-fuelled long-wave cycle to the 'rationalizing' downswing and as the heartland electronics technology has begun to diffuse to firms in DCs, so the technological gap between DCs and LDCs (which appeared to close somewhat in the 1960s and 1970s) has begun to widen once again. The potential impact of these developments on LDC industrialization is manifest.

2.3 CAD in the context of long waves

As we noted in the introductory chapter, and as we shall see in subsequent discussion, CAD spans both swings of the long-run cycle. In the earlier phase – that is in the late 1960s and early 1970s – it was a 'new' product, largely being used within the expanding electronics sector as an essential component in the design and manufacture of integrated circuits and printed circuit boards. But, recently (in the 'rationalizing' downswing), it has begun to filter down to established manufacturing sub-sectors where innovating enterprises have used it to optimize designs, reduce costs and shorten lead times in the face of growing competition. While the origins and development of CAD during the upswing are of intrinsic interest, it is clearly its role in the rationalizing downswing that is of greatest relevance to the subject under discussion.

More particularly we noted earlier that discussions of the likely impact of electronics were of a largely assertive nature. Not only do few empirical investigations exist [10] but with two exceptions (Rada, 1979; Hoffman and Rush, 1981) none of the research in this area considers the specific implications of the 'microelectronics revolution' for LDCs. This sectoral study on CAD aims to provide the sort of information necessary to evaluate the potential impact of electronics on LDCs. It does so by considering the *benefits* arising from the use of the technology, the *pace* at which it is likely to diffuse, and to which *sectors*, the *skills* required to utilize it and the extent to which it is filtering through to *LDC* plants. Only once these issues (and

others, such as the extent to which TNCs' location decisions will be affected by these developments) have been clarified will it be possible to assess the extent to which LDC industrial participation in the global economy will be affected in the last quarter of the twentieth century by electronics related innovations.

Notes

1 There are also, amongst many other variants, monetarist explanations of long wave cycles. However, we distinguish here between two sets of analyses, namely those postulating short-run cycles (in which we include the rump of monetarists and Keynesians) and those arguing for the existence of long-run cycles.

2 So named after his pioneering work (see Kondratieff, 1935).

3 Unfortunately Kleinknecht omits the scale on the vertical axis, so it is not possible to gauge from his presentation the intensity of the amplitudes observed by the various researchers.

4 The following section is based largely, but not exclusively, on the collective works of these authors. An alternative and broader view on the relationship between long-run growth and technology sees the industrial revolution as having been fuelled by technologies which increased physical energy and dexterity. The coming 'second industrial revolution' argued to be based on electronics-related innovations, provides a family of technologies to enhance the processing of information, and hence intellectual activities (see, e.g., Rada 1979).

5 These ideas are treated in greater detail, and are related to the advance of automation technologies in general, in Kaplinsky (1981).

6 For example, by the late 1970s, there was one car on the road in the United States for every 1.2 licensed drivers, with 84 per cent of households owning at least one car. In Western Europe there was one car for every two adults. See Transatlantic Perspectives (1981).

7 Much of the discussion in this section is elaborated in Kaplinsky (1981).

8 But, as Sciberras (1979) shows, this occurred to the disadvantage of firms pursuing this path in the television sector. Although the American firms were able to cut costs by taking advantage of cheap labour in export processing zones, manually assembled sets were less reliable than those assembled in automated plants and the Japanese firms were able to capitalize on automated assembly, and dominate the American market.

9 Thus in the mid-1970s around 40 per cent of all LDC manufactured exports were in the shoe and leather and garment and textiles industries (Chenery and Keesing, (1978).

10 That is outside of corporate research establishments. For example the West German government paid Macintosh Consultants 1.4 million DM for a study of the likely diffusion of electronics.

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Comparative advantage in an automating world

editor: Raphael Kaplinsky

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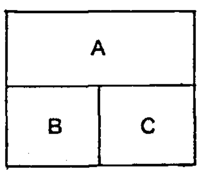

A—One of the world's most automated factories combining CNC machine tools and robots for the manufacture of robots. Source: Fujitsu Fanuc

B—Production line assemblying electronic watches by labour-intensive methods. Source: Hong Kong Government Office

C—This 64 RAM chip, smaller than the tip of a pen, is capable of storing 65.536 bits of information. Source: IBM

Notes on

Notes on contributors

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Julian L. Bogod trained as a mathematician and has been employed in the British food and electronics industries for many years. He was President of the British Computing Society in 1979-80, after which he took the initiative of forming the UK Council for Computing Development.

SUMMARY

Technology and the North-South division of labour
Juan F. Rada
Historically, too little attention has been paid to the impact of radical technical change on development strategies. In the current context of slow rates of economic growth, electronics based innovations are having a major impact on these strategies, particularly with respect to the international division of labour. The importance of considering dynamic technical change is illustrated by reference to the semiconductor industry where there appears to be a strong trend towards reducing the industry's dependence upon off-shore assembly in developing countries.

Some thoughts on changing comparative advantage
Gerard K. Boon
Automation induced by microelectronic technological change will ensure that a few Northern countries which have a lead on the basis of R and D, practical applications and faster diffusion, will have a comparative advantage *vis-à-vis* the rest of the world for some time to come. This will push the rest of the North—and even more so the South—into a dependency relation. Differences among areas and countries in the speed and direction of diffusion provide a basis for international trade, since it implies differences in absolute and comparative advantage. Given the pattern of output-specialisation, trade will remain strong within the North, within the South and between the two hemispheres. Nevertheless, the overall dependency of the South *vis-à-vis* the North will increase.

Electronics and industrial development
Ernest Braun
Electronics related technologies are becoming so central to industrial development that many developing countries are tempted to make them the cornerstone of their future strategies, as the steel industry was in the post-decolonisation era. However, it is important to distinguish between the different sub-sectors of the industry. In some, for example semiconductors, the innovation of automated technologies looks likely to erode the established comparative advantage of developing countries with low wage costs. In other sectors, such as consumer electronics, the signs look more hopeful. The high costs (both monetary and skilled labour) of entering the industry caution against misplaced strategies which emphasise the expansion of inappropriate sub-sectors in developing countries.

The Asian electronics industry looks to the future
Jeremy Clarke and Vincent Cable
In recent years, the electronics industries in some ldcs have become a focus of attention, due to their success in creating employment and promoting exports. This article assesses the future of the Asian electronics industry, distinguishing the early entrants, such as South Korea, Taiwan, Hong Kong and Singapore, from the latecomers, such as Malaysia, the Philippines, Indonesia and Sri Lanka. The former group has been able to develop a relatively independent industry, both with regard to 'mature' consumer goods industries and in relation to components. The new entrants, by contrast, remain heavily dependent upon MNC investment and technology. Three factors affect the future of the industry—domestic markets, protectionism and technical change. After assessing each of these factors, the article concludes on a rather pessimistic note, but points to the potential for greater intra-Third World trade.

Microelectronics and the garment industry: not yet a perfect fit
Kurt Hoffman and Howard Rush
The garments sector is a major source of exports and employment in many ldcs. If automated technology were to become available, comparative advantage might revert to the developed countries. This is lent further importance by the fact that the basic technology is similar to that used in the shoe and leather industries which are also major sources of ldc exports. Garment technology has remained remarkably static over the last century and there have been few technological barriers to new entrants to the industry. However, the introduction of microelectronics technology is beginning to affect this and the advantages of low wage costs are beginning to be undermined. This article warns that emerging microelectronics technologies may erode the comparative advantages of developing countries which fail to adjust to the changing technological environment.

Electronics and the technology gap—the case of numerically controlled machine tools
Staffan Jacobsson
This article is concerned with the introduction of electronic control devices ('numerical controls') in machine tools. This has provided substantial benefits to firms in that it saves both capital and labour, improves product quality and reduces the time required to bring new products onto the market. Whilst these advantages may appear to benefit developed countries disproportionately, the most significant benefit conferred is probably in relation to the saving of skilled labour. Since skilled labour is the major element in the developed countries' comparative advantage, it is likely that the diffusion of these machine tools will move comparative advantage in favour of the newly industrialising countries (NICs). However, the article concludes with the warning that advances in automation technology will probably reduce this temporary shift.

Is there a skill constraint in the diffusion of microelectronics?
Raphael Kaplinsky
The primary concern of this contribution is to determine whether the skills required to use microelectronics-related innovations are a constraint to developing countries adopting these technologies. Based upon a case study of the computer-aided design sector (which is growing very rapidly and provides substantial benefits to innovating firms), the conclusion is that, while the technology is often easier to use, the close relationship required between different users and between users and suppliers, makes it likely that the technology will be more appropriate to the operating environments of developed countries.

The UK course for computing development
Julian L. Bogod
If developing countries lack expertise in the utilisation of computers, some developed countries such as the UK may be able to provide aid in this sector. The UK Council for Development, consisting of representatives from academia, government and industry, was set up for this reason. This article offers a statement of its views, its aims and its intent.

RESUMEN

La tecnología y la división del trabajo entre el norte y el sur
Juan F. Rada
Desde el punto de vista histórico, apenas se ha prestado atención a las repercusiones de los cambios técnicos radicales en las estrategias del desarrollo. En el contexto actual de bajos índices de crecimiento económico, las innovaciones basadas en la electrónica están teniendo importantes consecuencias sobre estas estrategias, especialmente en relación con la división internacional del trabajo. Se ilustra la importancia de considerar el cambio técnico dinámico con referencia a la industria de semiconductores donde parece observarse una fuerte tendencia hacia la reducción de la dependencia de la industria en el montaje exterior en los países en vías de desarrollo.

Algunas ideas sobre la cambiante ventaja comperativa
Gerard K. Boon
La automatización inducida por el cambio tecnológico microelectrónico asegurará que algunos países septentrionales que se aventajan sobre la base de la investigación y perfeccionamiento, las aplicaciones prácticas y una divulgación más rápida, tengan una ventaja comparativa en relación con el resto del mundo durante bastante tiempo en el futuro. Esto empujará al resto de los países del norte—e incluso más a los del sur—hacia una relación de dependencia. Las diferencias entre diversas regiones y países en la velocidad y dirección de la divulgación sirven de base para el comercio internacional, ya que implica diferencias de la ventaja absoluta y comparativa. Dadas las modalidades de la especialización en la producción, el comercio seguirá teniendo fuerza dentro de los países septentrionales, dentro de los meridionales y entre los dos hemisferios. No obstante, aumentará la dependencia total del sur en relación con el norte.

La electrónica y el desarrollo industrial
Ernest Braun
Las tecnologías relacionadas con la electrónica están siendo tan centrales para el desarrollo industrial que numerosos países en vías de desarrollo se ven tentados de hacerlas la piedra clave de sus estrategias futuras, como ocurrió con la industria siderúrgica en la época posterior a la descolonización. No obstante, es importante distinguir entre los diferentes sectores secundarios de la industria. En algunos, por ejemplo el de los semiconductores, la innovación de las tecnologías automatizadas parece susceptible de reducir la ventaja comparativa establecida en los países en vías de desarrollo con bajos costos salariales. En otros sectores, tales como la electrónica de los artículos de consumo, las indicaciones parecen más esperanzadoras. Los elevados costos (tanto monetarios como de mano de obra especializada) que representa la entrada en la industria aconsejan cautela contra estrategias mal dirigidas que ponen de relieve la expansión de sectores secundarios inapropiados en los países en vías de desarrollo.

La industria electrónica asiática mira hacia el futuro
Jeremy Clarke y Vincent Cable
En años recientes, las industrias electrónicas en algunos países menos desarrollados ha constituido un foco de atención, debido a su éxito en la creación de empleo y promoción de exportaciones. En este artículo se evalúa el futuro de la industria electrónica asiática, distinguiendo entre los primeros participantes, tales como Corea del Sur, Taiwán, Hong Kong y Singapur y los recién llegados, tales como Malasia, las Filipinas, Indonesia y Sri Lanka. El antiguo grupo ha podido desarrollar una industria relativamente independiente, tanto respecto a las industrias "maduras" de productos de consumo como en relación con la de componentes. Los nuevos participantes, en contraste, siguen dependiendo muchísimo de la inversión y tecnología de las multinacionales. Hay tres factores que influyen en el futuro de la industria: el de los mercados nacionales, el proteccionismo y el cambio tecnológico. Después de evaluar cada uno de estos factores, el artículo concluye con una nota más bien pesimista, pero señala las posibilidades para un mayor comercio entre los países del Tercer Mundo.

La microelectrónica y la industria del vestido: todavía no ajustan perfectamente
Kurt Hoffman y Howard Rush
El sector de la industria del vestido es una fuente importante de exportaciones y empleo en muchos países menos desarrollados. Si se dispusiera fácilmente de una tecnología automatizada, la ventaja comparativa podría pasar de nuevo a los países desarrollados. Esto adquiere aún mayor importancia por el hecho de que la tecnología básica es semejante a la utilizada en las industrias del cuero y el calzado, que también constituyen importantes fuentes de exportaciones de los países menos desarrollados. La tecnología de las prendas de vestir ha permanecido notablemente estática durante el último siglo y apenas han existido barreras tecnológicas para los nuevos participantes en la industria. No obstante, la introducción de la tecnología microelectrónica comienza a influir en esto y empiezan a reducirse las ventajas de los costos salariales bajos. Este artículo constituye una advertencia de que las tecnologías microelectrónicas que empiezan a surgir pueden disminuir las ventajas comparativas de los países en vías de desarrollo que dejen de ajustarse a un ambiente tecnológico cambiante.

La electrónica y las diferencias tecnológicas: el caso de las máquinas-herramienta de control numérico
Staffan Jacobsson
Este artículo se concentra en la introducción de los dispositivos de control electrónico ('controles numéricos') en las máquinas-herramienta. Esto ha proporcionado beneficios importantes a las empresas porque ahorra tanto capital como mano de obra, mejora la calidad del producto y reduce el tiempo necesario para introducir nuevos productos en el mercado. Aunque estas ventajas parezcan beneficiar a los países desarrollados de una manera desproporcionada, el beneficio más importante que se obtiene está probablemente relacionado con el ahorro de mano de obra especializada. Como la mano de obra especializada es el elemento más importante en la ventaja comparativa de los países desarrollados, es probable que la divulgación de estas máquinas-herramienta traslade esta ventaja comparativa en favor de los países recientemente industrializados. No obstante, el artículo concluye con un aviso de que los progresos realizados en la tecnología automatizada probablemente reducirá este cambio provisional.

Editori

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Editorial

Raphael Kaplinsky

Adam Smith, writing in the latter half of the nineteenth century, attempted to explain the growth in labour productivity which was occurring round him largely in terms of human dexterity and organisational changes which, for him, were the significant factors underlying the division of labour. It was Marx, however, writing one hundred years later, who grasped the significance of machines. These machines, he argued, were not merely characterised by the form of power used, but also by the mechanisation of the tools which were being used, and in some cases, the automation of the control of these tools.

The development of this machine-power, continually subject to technical change, underlies the quite unprecedented growth of the world economy over the past two centuries. Over this period not only have the control of tool-devices and the quality of materials used grown in sophistication, but there has been a continual improvement in the physical power used to drive machines. The power source has moved from humans to animals. to water, to steam (wood and coal based) to the internal combustion engine, the electric motor and, possibly in the future, even to the atom.

But, some observers argue, in the same way as this growth in the control of *energy* underlay the 'first' industrial revolution of the past centuries, so the 'second' industrial revolution in the future will depend upon the control of *information*. And the key to this ability to manipulate and transmit information lies in the rapidly emerging technology of microelectronics.

This issue of the *Bulletin*, whilst less ambitious in scope than the grandiose recasting of industrial history described above, attempts to explore some of the possible impacts which microelectronics technology might have on the problems of underdevelopment. Its particular focus is an examination of its impact on international trade. A simple-minded explanation of its significance might be as follows: the existing international division of labour depends upon developed countries supplying technology and developing economies providing labour; but when there is no longer a need for labour, where lies the future comparative advantage of developing countries? But before we move on to a brief discussion of some of the issues involved in this subject area, it is appropriate to begin with a description of the technology.

Microelectronics technology: a brief description

To understand the significance of the new technology it is essential to comprehend the explanatory power of binary logic. Basically this enables one to count or manipulate ideas in an either/or (ie binary) framework. For example, consider counting: if we specify three switches, the first representing the number '1', the second '2' and the third '4', then we can count up to '7' by switching on all of the switches and to '6' by only taking into account the values of the second and third switches. In this way, by making a suitable number of switches available. we are able to count as high a number as we like via a series of either/or decisions. Similarly, logical systems can also be broken down into a series of binary decision-points.

What microelectronics does is to provide the capability to operate these binary systems cheaply within very confined spaces and without any moving parts. The key to this capability was the invention of the solid-state (ie no moving parts) transistor in 1947 which provided the basic either/or building block. In 1959 the integrated circuit, which allowed for the incorporation of more than one binary gate on each 'chip' (as these tiny pieces of silicon have come to be called) was developed and in 1971 a new programmable capability was provided by the invention of the microprocessor (often called 'the computer on a chip'). Progress over the years has been startling and sustained. For example, since 1959 the number of binary gates on each chip has doubled every year with an annual average reduction in costs of 30 per cent. At the same time reliability has increased and power consumption has declined.

As these chips have cheapened so has the range of uses. Beginning in the US in the military and space sector, the technology was initially associated with the introduction of new products such as computers and television. It was consequently a technology associated with expansion of production, trade and employment. However from the mid 1970s microelectronics came to be used as a substitute for mechanical control devices (eg watches, machine controls) and counting systems (eg cash registers). In this most recent era it has begun to penetrate into a vast number of existing products (from cars to children's toys) and processes (from driverless tractors to monitors of animal health) and serves the function of making these processes and products more efficient. So from an optimistic image of 'engine to growth', microelectronics has begun to make the transition to 'destroyer of jobs' (even though its labour-saving characteristics are only one feature of the advantages it offers to users).

Microelectronics technology cannot possibly offer something for nothing. Thus while the 'hardware' (that is the chips themselves) might be effectively costless the ability to get them to operate usefully through the medium of software (written instructions) is costly in terms of human intellectual effort, and requires skills which are currently in short supply. But the compensating benefits which the technology offers are impressive. Without suggesting that all uses provide the same benefits, or the same degree, or benefits in the same relative order of importance, it is possible to distinguish three different sets of benefits which can be, and have been, realised. These are:

a) *in product.* This includes new products (eg televisions), products with improved performance (eg watches), better quality products and products produced with a considerably shortened lead time;

b) *in materials utilisation.* Through optimisation procedures, this includes the very important category of energy-saving devices. It also includes a wide range of uses in which shapes are cut out of a sheet which is a characteristic of nearly all assembly industries;

c) *in process.* Here microelectronics related process innovations can be both capital or labour saving or both. Moreover they can also conserve on particular types of each of these factors (such as skilled labour, or space). Finally it offers [as we can see from Jacobsson's article] the very important capability of enhanced flexibility.

The links between microelectronics and comparative advantage

Of course, by itself, little can be held against the chip. It provides the potential to relieve humans from dull, repetitive jobs as well as to assist in the execution of intellectually challenging tasks. As such it offers the advantage of producing more and better products with less material and human input. Rather it is the form of social organisation within which it will be introduced that determines the nature and extent of benefits which will be reaped. Each of the various contributions in this *Bulletin* explores the likely impact of this technology with specific relevance to this social context, rather than in relation to an alternative, more 'appropriate' nexus of innovation. So, if the overall conclusion is that the introduction of the new technology (as it has come to be called) will have negative impacts, then it is essential to keep in mind the social context within which it is introduced.

Before we proceed to list some of the major issues involved in this subject area we ought briefly to remind ourselves of some of the developments which have taken place in the world economy over the past two decades. From an established division of labour whereby the developing countries seemed consigned to be processors of raw materials and suppliers of agricultural commodities, we have seen the entry in recent years of some newly industrialising countries (NICs) as major suppliers of manufactured goods and even of technology. South Korea's exports of manufactures, for example, grew at an annual rate of 36 per cent between 1965 and 1975; aggregate developing country manufactured exports grew from \$4.6 bn in 1965 to \$55 bn in 1975; and the share of developing countries in global manufacturing value added grew from around 7 per cent in 1965 to nearly 10 per cent in 1979. Not surprisingly, on the basis of this performance, the 1978 UNIDO Lima Conference set a target for the developing countries of 25 per cent of global value added in manufacturing by the year 2,000.

But both the achievements and projections occurred within the context of an expanding world economy in which there appeared to be space for a large number of producers and in which (particularly given near full employment in the developed countries) the benefits resulting from specialisation and comparative advantage appeared to be beneficial to most (powerful) trading countries. But now, as we enter the 1980s, the rising levels of unemployment in most industrial economies, associated with fierce competition in most sectors, suggests a different scenario. Moreover the potential productivity benefits offered by microelectronics—particularly in relation to the saving of labour—leads one to wonder whether comparative advantage can still be drawn on the same lines.

In exploring the specific links between the new technology and the changing pattern of comparative advantage, it is possible to establish four broadly different lines of argument. Whilst each of these can be justified on a macro- or sectoral-plane, it is an unfortunate fact that few sectoral studies have yet been undertaken to assess the detailed interrelationship between the new technology and trade. Thus the various contributions to this *Bulletin* [see also Ernst forthcoming] represent the first wave of studies which are being undertaken in this subject area. The results which are emerging are as yet largely suggestive and only time will tell whether they offer a realistic portrayal of the future. In discussing the four alternative scenarios, we will try to merge these two sets of micro- and macrostudies.

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a) Microelectronics will have a positive impact on developing countries comparative advantage

Here it is argued that there is no reason to believe that the new technology will diffuse more unevenly through the world economy than have previous technologies. On the contrary, by saving on specialised skills [see Jacobsson in this *Bulletin*] it is particularly suited to developing economies and consequently it will have a disproportionately positive impact on Third World comparative advantage. Moreover since the new technology is inherently a systems technology [see Rada and Kaplinsky in this issue] it may well be that it is easier to introduce in expanding developing economies in which there are fewer impediments to change, than in rationalising industrialised economies which have a long history of established work patterns.

b) Microelectronics will have little impact on comparative advantage

In this scenario microelectronics is essentially seen as one in a long series of incremental technologies. It has no major impact on economic activity (and therefore leaves the macro-world unchanged) and it diffuses through the world economy at the same rate as other types of technology. None of the contributions to this *Bulletin* would appear to support this view, but that may only represent the obvious fact that no-one who is unconcerned about the problem would bother to do research on the subject!

c) The diffusion of microelectronics technologies will be associated with a reduction in developing country advantage

There is a wide variety of different 'schools' in this scenario. One of them is represented by a form of 'long wave' theory. This builds upon the recognition of 50 year long wave cycles in the world economy which are associated with the introduction of major 'heartland' technologies. Each of these cycles is considered to have an expansionary upswing in which the new heartland technology is predominantly used for the introduction of new products, and a rationalising downswing in which the technology is used to enhance competitiveness in the context of growing competition.

Within this framework, the period 1950-75 saw the expansionary upswing of the microelectronics based cycle with full employment and a growing international division of labour. Now that the world economy is in the rationalising downswing with growing unemployment at the centre (partly fuelled by labour-saving microelectronics technologies), the 'space' no longer exists for peripheral economies. Trade barriers and increased competitiveness of developed country producers using the new technology thus undermine the developing country comparative advantage which began to emerge in the 1960s and 1970s.

At a less grandiose level, a number of sectoral studies seem to confirm this trend towards comparative advantage reversal. The contributions by Rada, Braun, Hoffman and Rush, and Kaplinsky in this *Bulletin* would seem to confirm the hypothesis that the use of the new technology provides significant benefits to innovating firms and serves to undermine the potential comparative advantage of developing countries using cheap labour and pre-microelectronic technologies. In some cases (semiconductors and garments, for example) it is already possible to identify examples of trade reversal. Only Jacobsson's article suggests that the introduction of the new technology will be associated with enhanced developing country comparative advantage. And even in this case, it is argued that it is likely to be only a temporary phenomenon.

Finally, a third set of arguments sees the introduction of microelectronics technology as associated with growing centralising tendencies in the world economy [see Rada's contribution]. In the context of the growing crisis in the world economy, and with the undermining of developing country comparative advantage by the use of the next technology, these transnational companies will be less likely to locate production in the periphery. This is precisely what appears to be occurring now within the electronics industry itself [see Clarke and Cable, and Rada].

d) The impact will vary between countries

Most observers (Clarke and Cable, Rada, Hoffman and Rush and Jacobsson) recognise that developing countries are not a homogeneous group. Some of the NICs have by now established a level of industrial sophistication which probably means that they will already have made the transition to 'industrial development'. This group of countries, they argue, will almost certainly be less badly affected than the non-NIC developing countries.

Some policy implications

The contributions to this *Bulletin* reflect the embryonic stage of research in this area. Consequently it is difficult to offer more than tentative policy conclusions (although each of the relevant authors do so in their more extensive research reports). However three conclusions stand out in importance.

a) The use of microelectronics technology

Braun cautions against the conclusion that developing countries should move into the production of electronics components. However it is overwhelmingly clear that the new technology represents a quantum leap in efficiency and unless developing countries adopt it in products and processes, they will be forced to retreat from world markets (particularly with respect to exports to industrialised economies) and to increase protection to domestic producers. The signs are that the new technology is relatively easy to use and requires fewer and less skilled operators and less of some types of maintenance and repair skills (Jacobsson and Kaplinsky). But the danger is that even if developing countries do introduce the new technology, trade barriers partly resulting from job displacement in developed countries may well close off trade opportunities anyhow.

b) The development of software skills

The 'old' view that underdevelopment is caused by an absence of skills has by now been exploded in the context of high levels of unemployed graduates in many developing countries. The irony is that many of these countries (particularly India) are exceptionally rich in the very 'software' skills which constrain the introduction of microelectronics in developed countries. It is an open question, therefore, whether this software capability could be a source of developing country comparative advantage in the future, or whether the absence of an 'organic' link between this skilled cadre and indigenous industry undermines the feasibility of this policy option. The contribution by Bogod suggests a role for developed country technical assistance in this area in further encouraging the production of software skills in developing countries.

c) Appropriate technology

Hitherto the introduction of microelectronics has been associated with the military sector and in meeting the needs of developed country producers and consumers. Little attention has yet been given to meeting the requirements of groups within developing countries, to take advantage of the significant benefits which the technology offers. By this we do not mean the development of the solar-powered video recorders suggested by one agency to meet the basic needs of Indian villages, but rather technologies such as irrigation-control systems (eg in drip-feeds), meteorological forecasting for islands characterised by microclimates and rural health care systems. The development of appropriate systems to meet developing country needs deserves far greater emphasis than it currently gets.

In conclusion, therefore, despite the 'underdevelopment' of our awareness of the specific impact of microelectronics related innovations we cannot fail to recognise their significance. For a whole series of reasons, the coming decades are clearly going to differ from the previous ones and it is important to bear in mind the technological dimensions of the changing world if appropriate policy responses are to be fashioned. At the same time it would clearly be foolish to ignore the political-economic context in which these technological developments are occurring. Technology cannot be seen as an 'abstract good' since it takes particular forms which reflect the interests of the innovating parties. And in addition since transnational firms account for such a large share of world trade in manufactures, any set of policy responses should be acutely timed to the likely reaction of TNCs to these changing technological, political, economic and social climates.

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Technology and the North-South division of labour

Juan F. Rada

Technology and development

Concern about technology from the point of view of development studies has been growing consistently since it was recognised that control of technology has often led to the control of development, the definition of its aims, and the determination of its pace. The debate has, more often than not, been unduly concentrated in three broad areas. The first has been the characteristics of the technologies to be used, especially, to ensure that choices correspond to development aims and the economic and skill endowment of a given country or region. Second has been the mechanism of transfer of technology (licensing agreements, use of patents, trade secrets and so on) aimed principally at improving the conditions of the transfer of technology for developing countries (eg Code of Conduct). The third element has been the development of science and technology policies to upgrade the technical infrastructure and to encourage innovation in developing countries.

This is by no means a comprehensive listing of all the intricacies in technology-development debates. Its purpose is mainly to highlight the absence of consideration given to two equally important elements. The first is the dynamism of technical change, which although commonly recognised, is seldom assimilated with all its consequences into the debate. Technology, whether for materials, products, processes, clerical work or communications is a constantly moving target, so that the initial choice of technology is only the beginning of a process of assimilation, up-grading, and finally, innovation. However in most planning processes technology is often regarded as given, with little emphasis placed on trying to forecast how technological change might alter export or import performance, industries and raw materials. Whilst forecasting these developments remains more a craft than a science, this does not constitute an excuse for avoiding some form of indicative assessment of technological change.

The above point is closely linked to a second, increasingly important area of development research, namely the effects of technological change on the international division of labour. In other words, how do dynamic technological developments affect comparative advantage and thus development and industrialisation prospects in particular countries or regions. This phenomenon is by no means a new one, although surprisingly little attention has been paid to it. For example, history tells us that technological advances in textile manufacturing changed the international division of labour for textiles. By the 1830s, the price of yarn was perhaps one twentieth of what it had been 50 years earlier, and the cheapest Hindu labour could not compete in either quality or quantity with Lancashire's mules and throstles [Landes 1976:42]. Similarly, the commercialisation of the Haber-Bosh nitrogen fixation process in the 1920s did away with one of Chile's most important sources of external revenue, the exploitation of natural nitrate. At one point, Chile supplied at least two-thirds of the world's nitrate requirements and the tax on exports was 80 per cent of Chile's total revenue.

The historical listing of such technological developments and their effects on the international division of labour takes us to several countries and continents and includes, among other things, the substitution of natural by artificial processes in the production of rubber (which has in fact rebounded due to increased oil prices and performance requirements), fibres, colorants, certain minerals and the current tendency of partially substituting alternative energy sources for oil. Most of these are based on high, capital intensive technology.

In a more speculative vein, and looking at the future rather than the past, several questions could be posed in the light of current and imminent technological change:

—widespread experiments (and even some pilot plants) are underway to produce industrial glucose and sweeteners out of cellulose through the use of genetically engineered micro-organisms. If these experiments prove to be commercially viable, what will be the effect on sugar demand and prices, and on the revenues of sugar producers?

—Copper has been substituted in a number of applications in the past, such as by aluminium for power transmission. It is now facing further substitution in other areas, such as by fibre optics in the field of telecommunications. This is not going to be a sudden development but an evolutionary one, over a period of years. Will this affect the aggregate demand for copper and eventually its price?

The first example deals with biotechnology, or more specifically, with the latest developments in genetic engineering whose consequences for the international division of labour remain largely unexplored. The time horizon for commercial developments are commonly acknowledged to be between five (some new pharmaceutical products) to 20 years (applications for mining processes) although some products are already available [Congress of the United States, Office of Technology Assessment 1981].

The second deals with substitution of materials, where considerable research has already been done. But the prospects for new human-engineering materials which are presently used for sophisticated applications make an increase in the rate of this research likely.

This interaction between technological charge and the international division of labour does not only affect the North-South division of labour, but also that among developed countries. A classical and often quoted example has been the substitution of precision engineering by electronic components in the watch/clock industry, which has led to the transfer of a substantial part of the industry from the traditional producer, Switzerland, to Japan and the USA. Today, Japan is the biggest watch/clock producer in the world. Of additional interest in this case is that these changes in product, which inevitably lead to changes in processes, also forced a shift in the supplies of materials, sales force and marketing structure. The bulk of watches/clocks left the specialised shops to find new outlets in supermarkets and general stores.

Development models

The complexity of the interaction between technology and the international division of labour makes it difficult to generalise about trends. Indeed a number of theories have been developed from several points of view, including the product-process cycle and factor intensity (ie labour-intensity vs capital intensity) explanations. Out of these two sets of theories a 'model' of the international division of labour has evolved. Put simply, this 'model' assumes that developing countries will develop and industrialise through the transfer of production of simpler and labour intensive products to them, while advanced countries will move up-market through more R and D and knowledge-intensive production. This view is implicit in the basic assumptions of the New International Economic Order, the Third World industrialisation programme of UN agencies such as UNIDO, and the Brandt Report.

Labour intensive assembly of non-electronic clocks and watches.

Information Service, Taiwan Authorities

However it does not adequately consider the interaction between mature, semi-mature and advanced technologies. A mature technology could receive a substantial shot in the arm by developments in other, apparently unrelated areas of technologies, and acquire a new dynamism. For example, despite considerable talk, and work, on the 'readjustment' of the industrial structure of the developed countries, they remain the most important steel producers, ship-builders, car-manufacturers and even textile producers. These industries were thought to be natural candidates to go 'South', but through innovation in processes and products some have remained viable in high-wage economies. Many factors enter into play here, the most significant being the changing technological profile of traditional industries. This shift in technological profile does not only diminish the importance of direct labour cost in total manufacturing costs but also permits a chain of improvements in terms of quality, turn-around-time, customer service, stock management, office productivity and so on. In some cases, an improvement in the 'customer service' content of a given product is far more important than its actual manufacturing cost.

In addition, in some areas, market fragmentation (a characteristic of high income markets) is accompanied by specialisation with a heavy technological content. A good example here is in the electronics sector where in the area of memories or microprocessors one generation (for most applications) replaces rather than overlaps another. For instance, 4 bit microprocessors represented 100 per cent of the world microprocessor market in 1972, 23 per cent in 1980 and will account for only six per cent in 1985. (Projections of Creative Strategies International 1981.) The situation is similar for memories, with a new generation replacing the old in cycles of about eight years covering first introduction, peak and obsolescence.

Thus it is only natural that as markets grow so do the number of specialised niches. These products niches need to be highly specialised in order to offer features which truly justify their existence. In electronics again, success in these specialised sub-markets is conditioned by high technology content rather than because firms concetrate on stable products, and this occurs in both products (eg Uncommitted Logic Arrays) and processes (eg equipment). Although it is not possible to generalise from the experience of one sector, one should bear in mind that what is important about electronics is not just changes in the industry itself, but the fact that it is becoming a *convergence* industry. It is indispensable for a growing number of sectors' activities and services in which the content and format of information flows are changing. The entire industrial and service structure is thus moving toward a higher technological profile, with an ever-increasing emphasis on streamlining the production of software through the use of more firmware (which writes software into electronic components) and increasing modularity. These in turn, will accelerate the process of change.

The context of current technological change

The wider context in which current change takes place is one of slow growth, and there are no signs that this will change in the foreseeable future. Under these types of conditions, two effects are relevant to this discussion. The first is that slow growth encourages, or in some cases, forces innovation in order to optimise the use of resources—thus the investment rationale is much more cost-drive than growth-driven. This is not to say that slow growth is the cause of an upsurge in innovation which as a process is far more complex than that. What it does mean is that the general conditions are more conducive to innovations (and their diffusion) than to increased production with stable technologies and products. The second consequence of low growth is greater competition, particularly on an international scale, which in turn creates political conditions for re-adjustment.

The globalisation of competition, particularly among multinational companies, and the upsurge of innovation constitutes a mixture which is increasingly conditioning the international division of labour. For instance, the nature of current technological change, especially information technology in its broader sense, deals with an area which by and large has remained unchanged since the 19th century, namely the office. The increase in office productivity or the streamlining of administrative activities to reduce 'overhead' cost is essential if companies are going to remain competitive. This shift in the way information is conceptualised opens completely new avenues that need to be explored. The transition of information from a purely organisational and cultural resource towards considering it as an economic resource implies that growing attention will be paid to the 'information intensity' of goods and services as a feature of the structure of developed societies. This also implies the rationalisation of 'information activities' as happened in previous epochs with regard to manufacturing and agricultural work.

Some general features of contemporary technological change

In the context described above, some general features of current technological developments can be tentatively foreseen. These generalisations are intended to contribute towards conceptualising the nature of current change, and they are inevitably, at this early stage, tentative in nature. Three categories will be mentioned here: the importance of science, the increasing dependence of production on capital, and the changing nature of information. In the final section we will discuss them in relation to the electronics sector.

a) The importance of science

One of the salient features of current and impending technological change is that its origin and early developments have been based on basic scientific research. This is true for semiconductor technology, biotechnology and is also becoming evident with regard to developments in materials-technology [see Braun and MacDonald 1978; Metropolis et al 1980; Editors of Electronics 1981; Gros et al 1979; Congress of the United States 1981]. As the theoretical content of technology grows, so does the skill mix required to absorb and develop technology. At the same time comparative advantages are conditioned by the science/technology endowment of a given country. In this sense, comparative advantages are deriving more from human activity and organisation than from nature (eg raw materials). In other words, production of goods and services is becoming more geographically independent as technology progresses.

These developments in the field of technology have another important characteristic which is relevant to our discussion—the need for sinergy. Today an innovation is seldom the result of developments in a single field. On the contrary, it tends to be a composite of many disciplines, some coming from seemingly unrelated areas. Examples of this type of sinergy are developments in genetic engineering which would not have been possible without computers; whilst development in computing would not have been possible without important breakthroughs in crystallography, metallurgy, and many other areas.

Consequently technology and its transfer is increasingly dependent on what is loosely called 'intangible knowledge'. This type of knowledge is not necessarily embodied in individuals but is rather the result of organisational systems and interaction. Two examples which have been clearly identified come to mind. The first is in the semiconductor industry where the use of patents, although normally practised, is not of great strategic value to companies. The industry relies much more heavily on trade secrets and a form of 'organisational knowledge' [Sterling, Hobe Corporation 1978; Kaplinsky 1982]. The high mobility of personnel in the industry, especially the transfer of entire teams, constitutes a more direct problem to companies than the infringement of patents. The second example is software which is in many cases not patented precisely in order to avoid disclosure of information that would make it easy to copy. In the field of genetic engineering a similar process seems to be taking place as research in this area moves from academia to industry.

Due to the elements mentioned we encounter two important implications for the international division of labour. The first is that the growing theoretical content of technology makes its transfer difficult, given the techno-scientific infrastructure of most developing countries. The second is the increasing 'embodiment' of technology into goods and services. This is due to the growing importance of 'intangible knowledge' and the incorporation of functions and features into products and equipment. For instance, when precision mechanical components are replaced by electronic devices (eg watches, instruments, etc) this process of embodiment of technology takes place since functions performed in the past by separate elements are combined in a single circuit which in itself is a system rather than a component.

The trend towards systems rather than discrete components makes the absorption of technology by stages or parts (explicit in the concept of unpackaging technology) more difficult. At the same time, because of technological and commercial pressures, manufacturers of all kinds are moving towards total systems, with the service component incorporated. A well known example here has been the 'turn-key plants' in manufacturing, but one could add transport, banking and manufacturing systems. The trend is towards integration, which has partly been made possible by the characteristics and economy of information technology and microelectronics.

b) The dependence of production on capital

The second main feature is that production is increasingly the result of capital. This general statement, which describes a long historical trend, needs some refinement. Historically, the best example is agriculture, which through capital intensive labour- and land-saving technology, increased productivity tremendously over time. The developed countries are today the largest producers of agricultural goods, with only a fraction of their popualtion employed in the sector (typically, between three and ten per cent of the working population).

The diffusion of any technology is dependent on its factor-saving characteristics—whether labour, capital, materials, time or a combination of all of these. For our purpose one aspect is of particular importance here, and this is the labour-saving effect or, in other words, the decreasing importance of direct labour cost in total manufacturing and business cost. The debate in this topic in the last few years has been massive, and consensus seems to exist on one point at least that while there are labour saving effects at some levels, particularly in unskilled and semi-skilled manufacturing activities, at the same time there has been an increased demand for skilled labour in design, R and D and knowledge-intensive activities. This is only natural since automation at this stage of its development is increasingly dependent upon these skills.

Without entering too deeply into the debate on the choice of techniques, what is of interest from the point of view of the international division of labour is that the labour saving bias of new technology precisely affects jobs which were thought to be most suitable for developing countries. This argument has often caused confusion, as if one were suggesting that labour cost is, or will be irrelevant, or that developing countries will become a sort of industrial desert. Three points should be made in this respect and some of them I hope to illustrate later through the example of the semi-conductor industry. The first is that the term 'developing country' is short-hand for a tremendous variety of structures and development strategies. Thus, for countries with large internal markets (eg India, Brazil, Mexico) the effects of technology, and also their capacity to negotiate technology, is quite different from those with small markets or with an export-led development strategy. Second, research on the international division of labour, particularly in relation to the future of off-shore activities, has concentrated to a great extent on the relocation of plants because of the nature of technology. These types of activity involved few countries and few industrial sectors and the conclusions do not necessarily apply to the impact of technology in countries that have followed a different strategy, nor with regard to the individual sectors which were considered to be potential candidates to relocate in the 'South'. This points out the need for further research, but at the same time it should be clearly recognised that what happens is that labour cost becomes *less* of a constraint for production (in as much as the relative share of fixed-costs increase, in some cases substantially) and not because labour costs become irrelevant.

What this says is that the industrialisation alternatives for developing countries are becoming narrower and more complex. A third clarification refers to changes in markets as producers emphasise quality of products and innovation in order to compete in conditions of low growth. This in itself changes the requirements of production in terms of the type and skill-mix required. The changes in markets should not be underestimated, especially because they shorten the time span of individual product cycles, often forcing structural changes and specialisation in industry.

c) Information

A final general feature, which I do not propose to go into in detail here, is the growing importance of information as an economic resource, or the growing 'information intensity' of goods and services. The fact that electronic components, computers and, increasingly, telecommunications operate in the same language opens the way to a new type of social and economic infrastructure. There are essentially two trends forcing changes here. One is the ever-growing amount of information that needs to be collected, processed and retrieved, and the other is changes in technology which reduce the cost and increase the reliability and flexibility of processing information.

This process, which has been called 'informatisation' of society, is one which simply accounts for the fact that in order to produce a good or a service, much more information is required than in the past. This is because research intensity, coordination, marketing and other business needs with a heavy information content, are growing. From the point of view of the international division of labour at least two aspects are of great importance here.

The first refers to the process of rationalisation and automation of office work which will increase overall business productivity while augmenting fixed cost. In this respect little is known about how these processes rapidly underway in the developed countries will affect comparative advantages. Whilst in the past technology has essentially been oriented to production processes, whether in the primary or secondary sector, what is now required is a broader view which recognises that productivity growth is increasingly dependent on information and clerical activities. In many industries already, the majority of the labour force is employed in clerical and professional activities rather than on the 'shop-floor'. The economic availability of information technology now makes it possible to address systematically the question of office productivity. Changes in this area, by altering relative factor cost, will undoubtedly affect location and investment patterns.

The second aspect, of more immediate concern, is the concentration of 'information intensive' sectors in some developed countries. These sectors involve time sharing services, consulting, data bases and banks, design processes, R and D, software developments and other types of services (eg banking). This is not only a question of concentration of service activities (in the 'tertiary sector' sense) but more importantly, concerns an increase in the *service content* of material production. In many areas it is no longer feasible merely to produce an item—it is also necessary to provide with it after sales service, repair, maintenance and the compatibility for upgrading.

The case of software is an example here. In the total cost of software over its entire product cycle.

maintenance constitutes 60-80 per cent of total cost, and development 20-40 per cent. For maintenance, however, a vast service network is required with a close contact with end-users. The bulk of the revenue during the cycle of the product software is then the 'service' of it rather than the original production. (This of course is not applicable to packaged software or dedicated machines.) Similar changes are forecast in the case of programmable machine tools where the provision of software, its maintenance and a connection with 'machining data bases' (MDB) or 'computer aided design' (CAD) systems might be essential. As has happened with computers, it is likely that the overall cost of manufacturing tools and machinery will be more dependent on the 'service' content of the goods rather than on the 'hardware'. Therefore, the process of concentration of 'information intensive' activities involves many old and new types of services as well as the 'informatisation' of material goods. With the changing technological profile of productive activities the gap in this area between developed and developing countries is most likely to increase if judged only by the projected expenditure in establishing informatics infrastructures. The issues involved in this area are extremely broad, ranging from questions of telecommunication agreements and use of satellites to the economically and politically difficult issue of Transborder Data Flow.

Some elements of the three main aspects mentioned above can be explored through the specific case of the semiconductor industry, which provides an important illustrative case of these trends due to its heavy technological content and the fact that it has been most extensively used in assembly plants in developing countries. At the same time progress in semiconductors is deeply conditioning trends in other industries, ranging from consumer and professional electronics to heavy capital goods. The intention in the next section is not to explore all aspects conditioning industry behaviour, but only those specifically affecting location and investment patterns. For reasons of space, one aspect of great interest in the case of this industry, namely technological behaviour, will be omitted.

The semiconductor industry

From the point of view of investment and location the main factors conditioning behaviour in the semiconductor industry are company structure, firm strategy and the characteristics of the national economic system. This statement is applicable to semi-captive and merchant (selling in the open market) producers rather than captive producers which operate with different rationales (ie IBM or Western Electric). In terms of the structure of the industry some important changes have taken place, particularly in the US industry since 1977. While in the early 1970s the industry was characterised by the existence of independent, technologically innovative, big and small producers, today the archetype seems to be vertically integrated companies, and the independent producers have become less prominent. By contrast, the five large Japanese semiconductor producers and the two largest European ones have always been vertically integrated. Thus the USA, where the most innovative companies have been based, has been the exception. But now, even there, most companies have developed corporate links or are wholly-owned subsidiaries of large corporations. For instance, if one considers even the US merchant market (ie those selling products in the open market) by the equity characteristics of producers, it looks as follows;

	%*
Independent (Texas Instruments, Motorola, National Semiconductors, Intel)	46
Subsidiaries and divisions of major corporations	16
Majority control by major corporations	19
Minority control by major corporations	6
Others (mainly small independent producers)	13

**based on 1979 sales figures*

If we consider the overall activities of the 'big league' firms we would note that some of them have themselves become vertically integrated corporations. Thus, unlike National Semiconductors and Intel (with over 70 per cent of their sales concentrated in semiconductors), the semiconductor operations of Texas Instruments and Motorola represent only 47 and 37 per cent respectively of total sales.

The reasons for this development in the industry are related to three main factors discussed above, namely capital requirements, cost of R and D and access to technology [Rada 1982]. This change in structure is accompanied by a growing number of captive and semi-captive production facilities, especially for integrated circuits. Automobile manufacturers, camera producers, office equipment companies and many others are recognising the importance of vertical integration as a way of ensuring supplies and also of distinguishing their final products in the market-place by tailoring electronic components to their own needs and systems. A sign of this trend is that in the US, 23 captive facilities were established in 1970 and 61 in 1980 [Bojert and Vieber 1981].

Thus the 'archetype' semiconductor company is increasingly becoming a vertically integrated one as technological and economic pressures force the producers of components into the production of systems, and systems producers into the manufacture of components. At the same time a risk-averting strategy is pursued to maintain a level of innovation and technological tie-ups that allow companies to quickly 'ride' the learning curve and defeat or neutralise the natural economies of scale of very large vertically integrated TNCs.

But whilst the above may be an accurate reflection of the mass production merchant market, it is also true that as the market expands so do the number of niches. So one can expect numerous new entries and success stories in specialised circuits and equipment, and also the subcontracting to highly specialised companies of part of the production process.

But in this industry, perhaps more than any other, market share needs to be heavily qualified by two considerations. The first is by market segment where, for example, in the case of microprocessors, Intel is on top, mastering the most complex technology. The second is what one might call 'technology share' which occurs due to second sourcing. For example, American Micro Devices (AMD) which only has about two per cent of the total US semiconductor market, has a much larger presence in integrated circuits. In the 4-bit microprocessor segment, its direct share was 57 per cent (by volume), but if we consider indirect shares, AMD accounts for 70 per cent (by volume) of the market due to the fact that 13 per cent is second sourced (via licences) to companies such as Fairchild, Hitachi. NEC, Philips and Diemens. Siemens in turn owns about 20 per cent of AMD (Creative Strategies International 1981).

Second sourcing, equity participation, technology tie-ups and joint research efforts all suggest that to look at the main actors from any particular angle is necessarily a partial view, and the greater the segmentation of the market, the more complex the analysis of actors will become. In addition, the conditions under which the different companies operate varies. For instance, the largest portion of equity in Japanese companies is held by financial institutions or other companies, while individuals hold a relatively low percentage as compared with US companies. Furthermore the Japanese industry's vertical structure affects the cost of capital because it allows profits from one division to be used to finance investment in another. The result of this structure is that Japanese semiconductor companies employ significantly higher debt ratios than US semiconductor companies. Typically, they maintain debt-to-capital ratios of 60-70 per cent while US companies range between 16 and 18 per cent. Consequently the cost of capital to Japanese semiconductor companies is significantly lower than that of the US companies, and this is largely a result of the higher debt ratios employed by the Japanese. As a result their required rate of return on investment is lower than those of US companies. Thus, in the period 1977-79, the typical US electronic company earned 16.3 per cent on capital employed, whilst in the same period the Japanese companies earned 7.5 per cent on capital. (Rate of return for capital is defined here as net operating profits after taxes as a percentage of average total debt and equity capital employed.) As a result of these elements, Japanese companies can accept lower profit margins, lower rates of return on capital and a lower cost of capital. Under these conditions the cost pressures on Japanese producers are different and to a large extent this explains their emphasis on product quality through rapid automation, which requires large outlays of capital. Thus if in the 1970s the recipe for success was volume/yields, today it is volume/yields/quality and in order to achieve it more complex, expensive and automatic plants are required.

The Japanese have come to be noted for the high degree of automation of their assembly process, with the level of cleanliness approaching that of wafer processing. They tend to rely more on automatic equipment than on in-line inspection. Many changes are also taking place on types of materials and packages in an effort to increase quality by merging together production and design engineering. The approach is 'hands-off' whenever possible. However it is worth noting that the pace of automation varies for different companies and products. For memory devices, with high margins and a massive market, the trend to automation is strong. For other more expensive and low margin devices, the pace is slower, and packaging and assembling tend to be a relatively smaller proportion of the total cost.

Now, extensive use of automatic equipment and expensive capital intensive plants allow producers to reduce—or at least not expand—off-shore assembly in developing countries, which in the past has utilised relatively labour-intensive technology. In addition the cost of operating capital intensive plants tends to be relatively similar, independent of location. This points to one of the notable differences between Japanese and US producers, which concerns the use of off-shore plants as a major source of capacity. The data suggest that Japanese firms do not utilise off-shore manufacturing to support a significant percentage of output (both by volume and value). Nevertheless partly due to their use of automated techniques, they are able to compete successfully on price.

The reluctance of the Japanese to rely on off-shore plants is due to the belief that quality cannot be assured in labour-intensive production. Their latest significant off-shore investments are in the USA and Europe mainly because of the need to have access to markets and to avoid trade friction. US companies operating under very different conditions are forced to follow a strategy which tends to maximise short-term profits. Thus the constraints on cost are very different. especially in terms of capital investment in fully automated plants. In addition US custom regulations (items 806.00 and 807.30) have encouraged the use of off-shore facilities. These regulations only tax foreign materials, and value added abroad to imported products. However, despite the upgrading of off-shore plants (eg, adding testing in some of them) the value added outside the US has been consistently declining, in the case of integrated circuits from 57 per cent in 1974, to 39 per cent in 1978. This is due to the increasing value of the parts of devices produced in the USA [US International Trade Commission 1979:14].

A comparison between the USA and Japan shows the following:

Approximate off-shore production of US and Japanese semiconductor companies as percentage of the value of total domestic production

	1978	*1979*
Japan	3	3
USA	37	na[1]

Source: based on data from the Bank of Asia, *The Semiconductor Industry in Japan*, Hong Kong 1980. and US International Trade Commission, *Competitive Factors Influencing World Trade in Semiconductors*, Washington 1979.

[1] A fair assumption would be that the percentage remains the same.

By far the largest number of off-shore plants belong to US producers. Thus of 112 off-shore plants in 1981 assembling semiconductors, 69 per cent belong to US companies, 12 per cent to European and 19 per cent to Japanese producers.

In terms of labour-cost, an item of particular importance to US producers, wage differentials *vis-à-vis* off-shore facilities remain large—typically a ratio of 1:4. Nevertheless, if labour cost were the prime consideration for choosing, fabricating and assembling sites. many companies would have moved to lower wage countries as relative wage costs have risen in some of the more successful NICs. However, although some movement has taken place, by and large the industry remains in the areas of original investment. Hence. large producers have relatively few plants in very low wage countries such as Thailand 5, Indonesia 3 and India 3. By contrast they have 16 plants in Singapore, which is one of the most expensive countries in terms of wages for assembling-type operations. However it should be emphasised here that labour cost has never been the only consideration for choosing off-shore sites. There are many other elements including infrastructure, political considerations, tax and capital incentives and conditions for foreign investment.

These impending changes in the structure of the industry have not entirely sunk in yet, but the process of rationalisation and streamlining is likely to accelerate in the next few years. The consequence of this rationalisation will be to affect off-shore locations, levels of employment, increased vertical integration and capital intensity, and last but not least, the industry will become more fiercely competitive. For example, Siemens is slowly digesting its acquisitions and has overlapping off-shore plants with Litronix (with which it has recently formed equity links) in Singapore and Malaysia, while a Litronix plant in Mauritius has been closed. General Electric overlaps with an Intersil plant (which it has just purchased) in Singapore. The same pattern is applicable to many other companies in terms of plants, sales, marketing structures, and, of course, R and D.

In the short run, especially for smaller producers, off-shore locations (particularly in Asia) are attractive, since they are far less capital intensive than highly automated domestic plants. For those with heavy commitments overseas, such as Fairchild, automation of some of these stages of existing off-shore operations are only rational. But at the same time we have seen in the last year the birth of specialised assembly companies on-shore (eg California) with highly automated lines, lower turnaround time and greater proximity to customers.

Whilst smaller companies and new entrants might turn to subcontracting assembling operations off-shore, as well as on-shore, rather than overstretch their managerial and financial resources with wholly-owned operations, the fact is that the larger the company and the more vertically integrated, (which, as we have argued, appears to be the trend) the less the use of off-shore plants in terms of numbers as well as size. Thus for similar value for semiconductor sales NEC has three off-shore plants and National Semiconductors six: Hitachi two and Fairchild seven; Philips two and Motorola eight. As fixed costs become larger as a proportion of total cost and the value added in semiconductor manufacture operations (as opposed to assembly) grows, we shall see an acceleration of the rationalisation in the present distribution of plans. In addition, as quality becomes crucial for competitiveness, assembly will change substantially with automation and the use of clean rooms. At this point fully integrated manufacturing plants will become more economical than the fragmentation of production.

Three elements are, then, conditioning current changes in semiconductors. The first is the alteration of firm structure, due to the increasing capital and R and D needs, including basic research, leading towards larger, vertical integrated companies. Secondly, automation is increasing the fixed cost of production and changing the skill-mix in plants. This diminishes the relative importance of low-wage direct labour cost. Thirdly, and closely related to the second point, is the drive for quality, which is forcing automation and the use of highly capital-intensive plants.

Other elements that condition the use of off-shore plants, eg tax and capital incentives, are also decreasing in importance as many developed countries have put into effect plans and incentives to encourage the electronics industry and which, in some cases, might neutralise, in relative terms, the advantage of off-shore locations. A case in point here is Scotland and France, both of which have been successful in either attracting foreign investment or developing technological ties and cross-licence agreements. The largest investments in integrated circuits (outside the companies' own countries) have taken place in Scotland in the last three years.

Conclusion

All the elements discussed in this article can be summarised by one main conclusion. This is, that for development studies, whether in the economic, social and political field or in specific areas of human resources and transfer of technology a very dynamic view of technological change should be incorporated. The complexity of the issues involved makes it necessary to take a transdisciplinary appraoch to research and to begin questioning very systematically some of the basic assumptions of commonly professed development theories. Prospective technological assessment should become a central element in economic studies and planning, and should deserve far more attention than has been the case so far, especially in the context of work on dèvelopment.

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Some Thoughts on Changing Comparative Advantage

Gerard K. Boon

Introduction

In the next two decades the pace of automation in the industrialised countries will increase significantly as a consequence of current developments in microelectronic technology and a diffusion of elements of this technology to virtually all producer and consumer goods industries. The speed of diffusion is accelerating and will probably attain a momentum which can neither be stopped or reversed. The most important feature of this technological development insofar as manufacturing industry is concerned is that it enables the automation of the 'discrete parts' industry. This industry produces products which are assembled from smaller parts. Therefore, after automation, these industries will become comparable to capital intensive continuous process sectors such as chemicals, petrochemicals and cement. The discrete part industry, in its production and assembly phase, provides the bulk of the industrial employment in all industrialised countries. A segment of this industry, particularly that which produces capital goods and technology, is highly labour- and skill-intensive. In this type of output, the comparative advantage of the industrialised world is high.

Another characteristic of the microelectronic technological revolution is that it is diffusing to the service and agricultural sectors as well as in industry. It therefore poses a formidable adjustment problem to the societies of the developed world, who will most probably have to undergo changes in structure in order to cope with the sharp reduction in formal employment which automation involves.

Since the technological change with which we are dealing is, in my view, of such importance that it will evoke changes in the structure of both developed and developing societies alike, it will have an inevitable impact on comparative advantage, invalidating the *ceteris paribus* assumption of trade theory. It is therefore more realistic to assume that everything else will change, as a direct and indirect consequence of this microelectronic technological change. Hence, whilst comparative advantage will also change, the question is how, and to which extent? The short answer would be, nobody knows! Nevertheless it is worth assessing the question in more detail, since it clearly is of utmost importance.

The present international division of labour

According to the neo-classical theory of international trade, the so-called international division of labour is based on differences among nations and regions in relative comparative advantage in the production of outputs. Indeed, it has been mathematically 'proved' (under the very abstract and restricted conditions of this theory) that in the long run international trade equalises the incomes of capital and labour in all countries. However, there is, as usual, a large discrepancy between theory and practice, and the theory is probably more useful in explaining the past than the present. A major reason for this discrepancy between theory and the real world of international trade is the politics of international and national relations. In other words, it is not only economic factors which play a role, but also political ones, which are, in turn, influenced by power and other social and cultural relations. Thus, according to economic theory, protectionism will lead to a loss in welfare, but trade unions, representing workers in economic sectors which have to decline or disappear, may feel differently.

Developing countries, on the basis of neo-classical trade theory, should in some cases refrain from entering into certain capital-intensive production activities. However their governments may feel differently. Strategic considerations as well as economic ones may dictate national development objectives which contrast with those suggested by international trade theory. This implies that trade theory, and with it the concept of comparative advantage, has to be modified. It must be seen not only in a purely economic context, but together with extra economic considerations of a social, political and cultural nature. The drawback of introducing a more complex concept of comparative advantage is that it becomes less clear-cut and therefore less powerful as an explanatory theory. Despite these reservations, the neo-classical concept of comparative advantage still has some explanatory and practical significance, as I have shown in my own research on international trade in footwear, fibres, textiles and clothing, as well as on the technologies making these products [Boon 1980a, 1981]. One of the conclusions which I reached was that the output specification of the traded goods is the major explanatory variable. Hence goods with simple output specifications are the ones in which less-industrialised and newly industrialising countries have, in principle, a comparative advantage, whilst mature industrialised countries have an advantage in goods with complex specifications and characteristics. This basic principle holds not only for industrial products, but for all activities and outputs which are tradeable, including intangible services, know-how and information [Boon 1981, 1982].

Thus I believe that the major factor explaining comparative advantage is the difference in output specifications rather than in the price differential between labour and capital in different countries, which, according to neo-classical trade theory, is the major explanatory parameter. Nevertheless all this is still subject to the constraints mentioned—political, social and cultural considerations may outweigh economic ones in explaining actual trade patterns.

The future

How will the diffusion of future technological advances, specifically of those resulting from the application of microelectronics, affect international trade? Such a very generally formulated question is hard to answer and we have to break it down into smaller components. The effects clearly will depend on the diffusion of microelectronic technology into other processing technologies and products. Let us start with the latter, the outputs. The demand for final outputs is enhanced if their price is falling for equal utilities (say quality), or if qualities, yielding higher consumer satisfaction, are increasing for equal prices, or when prices and qualities for the consumer both improve. Hence, if the application of technology embodying microelectronic components allows producers to achieve any or all of the objectives mentioned, they will be anxious to acquire this new technology.

Diffusion cannot be explained by prices, qualities, demands and supplies (ie market forces) alone, since all these occur in particular social-economic environments, which in turn are conditioned by the formalised and non-formalised institutional frameworks which define a society. Clearly societies differ, and therefore the rate at which technology diffuses differs amongst countries, whether located in the North or in the South. Different diffusion rates among countries imply future differences in comparative advantage and therefore a potential basis for international trade. Let us first examine the North.

The North

The North consists of North America, Japan, Western Europe and the socialist countries. Microelectronics technology is most strongly developed, diffused and applied in the USA (where it originated) and Japan. Both are engaged in intense competition, both are market economies, dynamically oriented and aggressive. Both countries are about equal in strength as far as microelectronic capability is concerned, with the US probably somewhat stronger in the development of the technology and Japan in the application. In Europe the scene is rather different, since it neither adheres to a dynamically or aggressively market oriented ideology and economic system nor is it socialist in the Eastern European sense. It lies somewhere in between these extremes.

The diffusion of microelectronic technology in Western Europe will therefore be slower than in Japan and the US, but considerably faster than in Eastern Europe. This could imply a further weakening of the alliance of the free market economies and a drifting away of Western Europe towards a degree of economic and political neutrality. Moreover, on the basis of projected differences in the rate of diffusion of the new technology in the US, Japan, Western and Eastern Europe, comparative advantages among these areas will be affected accordingly. This will ultimately result in increasing technological dependence, and hence *economic* dependence, and, in the somewhat longer run, possibly some erosion of the political power of the Western- and Eastern European areas. But clearly the extent to which this occurs depends on Western Europe's responce to the challlenge, and this cannot be completely foreseen.

The South

What about the South? Clearly we also have to make some differentiation here. Not all countries are at the same stage of development: in one group are the newly industrialising countries (NICs) such as Taiwan, South Korea, Singapore, Mexico, Brazil, Argentina and India; and in the other group are the remaining countries, which are at a lower level of industrial development. Whilst such a distinction is very general, we cannot here discuss the subject in any other way than by using such high levels of aggregates.

In some of the NICs certain capital goods containing microelectronic elements are already produced. It is conceivable even that some of these countries (eg Taiwan and South Korea) will become exporters of relatively simple capital goods (machine tools for example), containing microelectronic components. In fact, this already occurs to some extent. It is even conceivable that a select number of the NICs may become 'developed'. However, unlike South Korea and Taiwan, the economies of Mexico, Brazil and India have a much more dualistic, even pluralistic, structure and it will be some time before they qualify for admission into the club of the rich countries. In my view microelectronic technology will not diffuse that rapidly in this latter group of countries, and only the best enterprises (as to internal organisation and quality of output) will experience relatively rapid diffusion. The basic reason for this is that the new technology is a geo-technology of the North, conditioned by the particular situation in that industrial area and therefore appropriate as an output and an input there. Only enterprises with a comparable conditioning in the South, (such as affiliated firms of multinational companies or national companies exporting and competing on the world market with the North) will introduce the new technology. Moreover in Latin America the NICs tend to have a more inward looking development strategy and, therefore, in some cases the new technology will diffuse on the basis of non-private economic feasibility criteria, to increase the local technological capabilities and to decrease technological dependence. Similar considerations may play a role for India. In the remaining countries of the South the diffusion of the new technology will be even more restricted.

North-South

Finally, exploring North-South interrelations, particularly their trading relations, how will automation on the basis of microelectronics influence comparative advantage?

Let us first focus on a more general point already mentioned. The new technology, involving the full or partial use of microelectronics, is a geo-technology of the North, particularly of the USA and Japan, and is particularly appropriate to those areas. Clearly it is a considerably less appropriate technology for areas with a different culture or economic environment. (A few exceptions have already been mentioned.) In such a situation the North always tends to increase its comparative advantage in the production and application of the new technology, and the NICs and the rest of the South face a deterioration in their comparative advantage.

In the face of this growing technological gap, how will the international division of labour in industrial and other products be affected by this new technology? I stated above that output specialisation is the major factor underlying comparative advantage. This product specification is now dispersed over the world in the following way: simpler outputs with common specifications have become the speciality of the developing countries, whilst outputs with specific characteristics as to quality, colour, smell, taste, fashion, and more sophisticated production technologies (all of which are characteristics of the discrete parts industry) have become the speciality of the developed countries. At present it looks as if the new microelectronics technology is particularly suitable for the production of these special outputs, and less so for the production of common outputs which can be mass produced on conventional automated machinery requiring little skill. Therefore, the use of the new technology for the relatively small batch production of discrete parts will inhibit a tendency for these outputs also to move to the newly industrialising countries. Thus the new technology will enable the North to remain competitive in its present output specification for some time to come.

The simpler, more mass produced outputs, have generally speaking already moved to the NICs. In this output new technological advances based on microelectronic components diffuse more slowly, and therefore for the immediate and near future, there is no reason to believe that the international division of labour will be reversed. In certain cases a roll-back of the international division of labour has occurred, but mostly it concerns assembly rather than production activities and these are exceptions rather than the rule. However, for mass produced products now produced by fixed rather than flexible production systems, changes in production technology will undoubtedly also occur. Since these systems are already labour-extensive, the introduction of more flexible technology will enable greater variety in the product mix, which is an aspect of quality and fashion, rather than a displacement of labour and hence a reduction in the cost of production. But the introduction of robots in manufacturing and assembly, through its impact on labour utilisation, will nevertheless have an effect on comaprative advantage since the international division of labour in certain industrial processes occurs precisely because labour in the North virtually refuses to undertake certain tasks on the grounds that the work is unhealthy, dangerous, extremely boring or a combination of all three. The introduction of robots for this type of work is advancing rapidly in the North, and the South consequently stands to lose as a result. Further, decisions to move production to lower labour-cost areas are based not only on labour cost differentials, but more importantly on other factors, such as docility of the labour force, and the opportunity to operate on a multiple shift basis. Since numerically controlled machinery and robots can work 24 hours a day with little or no supervision, the comparative advantage of the North will benefit accordingly.

As I suggested earlier, the new technology will diffuse in the various countries in the North and the South at different rates. This implies that there will be all kinds of segments and niches where, on the basis of the output-speciality-comparative advantage criterion, international trade is bound to flourish. Further, if the diffusion of the new technology in the North does have a dramatic impact on formal employment opportunities, new social contracts in the North will be imperative. Almost certainly more leisure time for

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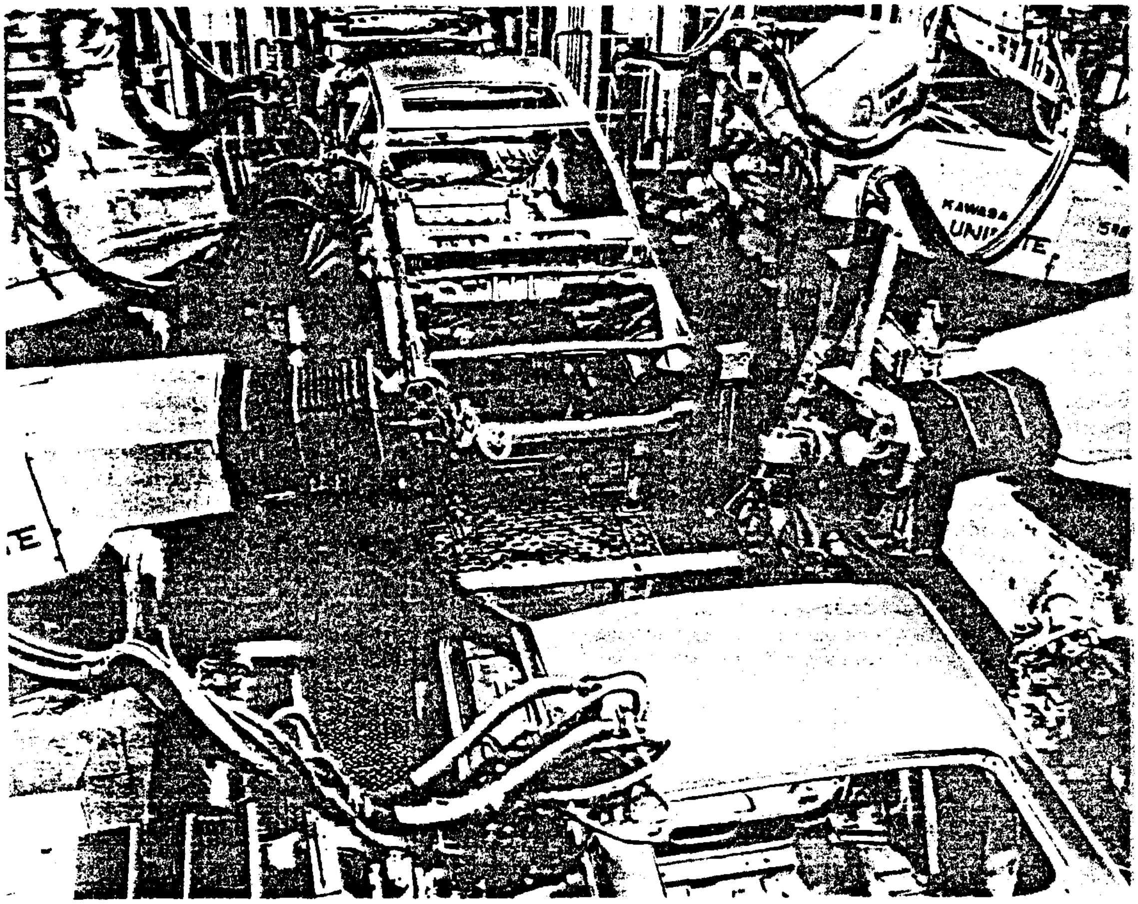

Japan Information Centre, London

Welding robots on car assembly line.

the masses will result, which will create new demand patterns involving not only demand for foreign travel with its consequences for the tourist industry in the South, but also the desire to maximize the purchasing power of given incomes, which implies changes in international trade.

So far the information aspects of automation and the latter's impact on services in general has hardly been mentioned. Yet, the Northern geo-technology of microelectronics will have a major impact on the concentration of information: the know-how, know-where and know-whom. This implies a further detrimental effect on comparative advantage, since those who control information control, to some extent, economic and even political life. Undoubtedly the South will also try to reduce its dependence in this area. The more it operates as a block, the more chance it will have of successfully reducing the degree of dependency.

Conclusion

Microelectronic technological changes will affect comparative advantage in the following way: a few Northern countries, which have a lead on the basis of R and D, practical applications and diffusion will have a comparative advantage *vis-à-vis* the rest of the world for some time to come. This may push the rest of the North into a dependency relation—but even more so for the South. Nevertheless, differences in the speed and direction of diffusion amongst areas and countries creates in itself a basis for international trade based on differences in absolute and relative comparative advantage. On the basis of the output-speciality criterion trade will, in principle, remain strong within the North, within the South and between both, although it may in the short run decrease somewhat. Much depends on responses made to this technological challenge in those countries which are initially dependent. If the response is defensive, trade may suffer. Finally, for the NICs and possibly even for the South as a whole, the new technology may also open up new trading opportunities. Still, the overall dependency of the South *vis-à-vis* the North (although in fact differentiated by country) will, on the basis of these Northern developed and controlled technologies, undoubtedly increase. However, since a similar phenomenon, although different in magnitude, will occur in the North itself, a different economic and political power structure may emerge. This could imply a more pluralistic North-South relation, which in its turn, could affect patterns of comparative advantage and hence the international division of labour.

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Electronics and Industrial Development

Ernest Braun

Introduction

A school of thought is beginning to emerge which regards the electronics industry as an essential element in the strategy of building an industrial economy. As in a previous wave of industrialisation in which the steel industry was regarded as fundamental—the foundation upon which other industries could be built—so now the electronics industry has become a symbol of industrial achievement. The reasons for this shift of view are to be found in some features of the electronics industry: its products are extremely varied and are used in an increasing number of other industrial and consumer products; the industry has come to be regarded as the heart of contemporary 'information society'; modern microelectronics and computing are considered crowning achievements of the scientific age.

The electronics industry consists of a variety of disparate sub-branches. In a simplified scheme, we may consider the industry to be divided into electronic components, consumer electronics, industrial electronics, telecommunications, and computers. Each of these sub-branches could be further divided. The electronic components industry, for example, manufactures active components, now mostly made of semiconductor materials and therefore known as the semiconductor industry, and passive components, such as resistors, capacitors and circuit boards.

It is very tempting to think of the semiconductor industry as the true cornerstone of an industrialisation strategy, because it lies at the heart of the electronic industry by providing the bulk of its active components. It is easy, but wrong, to identify the electronics industry with the manufacture of semiconductor devices. It is equally easy, and equally wrong, to confuse achievement in the semiconductor industry with the attainment of the general goals of industrialisation. It is not the purpose of this article to rehearse the well-known arguments in favour of industrial production as an economic activity supplementary to agricultural and mineral production, but rather to examine the electronics industry, and particularly the semiconductor industry, to illuminate its potential as a cornerstone of a policy for industrial development.

The semiconductor industry

The products of the semiconductor industry range from rectifiers and transistors, the so-called discrete components, to a large variety of integrated circuits of varying sophistication, right up to the most advanced microprocessors and memory chips and special purpose circuits. There are several very specific features of the semiconductor industry which distinguish it from other industrial branches. The main features are: high capital intensity; very high sophistication and dependence upon rare specialised scientific and engineering skills; high degree of interdependence within the industry and with specialist suppliers; and dominance of US know-how and US markets.

Although the semiconductor industry provides a prime example of the successful entry and growth of very small entrepreneurial firms, it also provides a classic example of maturation of an industry. In the early days of the industry, a few bright ideas, a little capital and plenty of hard work went a long way toward success. Many of the firms which started from scratch in the 1950s and 1960s have become industrial leaders, although many have failed to make the grade and have disappeared into oblivion. The capital required to enter the industry has become steadily larger, especially the entry fee into the select club of companies producing very large-scale integrated curcuits (vlsi). INMOS, the company funded by British public funds through the British Technology Group (formerly the National Enterprise Board) has £50 mn as its starting capital. This sum should prove just sufficient to give the company a chance to become a major competitor in advanced memory and microcomputer chips.

Not only is the entry fee into the semiconductor industry high: it has become a capital intensive industry in every sense of the word. Continued need for high capital investment has caused even some of the most successful firms to run into cash-flow problems and to become prone to being taken over by industrial giants with plenty of cash. Many a proud success of entrepreneurial skill of the 1950s and 1960s has now become a member of some major international group whose origins lie in the dim past of industrial history.

With increasing capital intensity. the industry is. of course. becoming less labour intensive and. to compound this problem, its labour requirements are mostly for people with highly specialised skills. For despite this apparent maturity of the industry after about 30 years of existence. its products and production methods are still changing very fast. and this change is backed by a vast army of scientists, engineers and technicians working in research, development and design.

Design has become a major preoccupation of the industry. taking its place at the side of the old preoccupation with yield of good chips per processed wafer. There are two major avenues of design: optimal chip design for mass produced circuits and design of special chips for relatively specialised applications. Additionally. there is the compromise of 'customised' design, using either standard chips or so-called undedicated logic arrays. The design of the latest microprocessors on the market takes between 100 and 200 person years of effort, despite the use of incredibly sophisticated computer aids. Computer designs computer. but not without the massive intervention of teams of highly trained. highly skilled. highly educated designers. ideally headed by chief designers of true genius. All this enormous design effort is spent in order to make a chip of the highest performance at the lowest possible price—for competition is extremely severe and neither inferior performance nor a premium price are tolerated by the market.

The more specialised applications are slightly easier to cater for. The design aims to achieve the function without optimal use of silicon. as the price is relatively unimportant. The design process consists of selecting pre-designed building blocks—stored in the computer—and interconnecting them suitably. An extreme case of this approach is to have semi-finished chips with arrays of logic gates—the building blocks referred to above—and leave the final interconnecting stage to determine what sort of device it shall be. It is even possible for sophisticated groups of specialists requiring specialised chips to produce their own design and have it made by a chip manufacturer in small numbers. Hence the concept of the 'silicon foundry'. an analogy with the casting to order of a customer's model in metal working industries.

The number of firms capable of doing all, or even some, of these things is quite small and the mobility of people within the industry is quite high. There is of course a premium on know-how: yet there is a surprising degree of sharing of general information. Everybody in the industry knows everybody else. and everyone knows the general drift of things to come. The state of the art and its short-term development are shared knowledge among the initiated—competitive advantage is gained by being just that little bit better that little bit sooner.

The vast amount of research effort does. of course, produce a large number of new devices and, infinitely more important, new ways of making new devices. Much of the vital detail of this information is kept confidential. Anything that cannot be kept secret is covered by patents and there is a lively trade in patent licences amongst all the manufacturers. The aim of the game is to exchange licences, rather than pay licence fees. Only by having a valuable portfolio of patents is it possible to make sure that other people's vital patents will be available when required.

All these features show an extraordinary degree of interdependence within the industry. Fierce competitors they may be, but they all know that they are in this business together. But who are they? Predominantly the American semiconductor industry. with the Japanese, after years of strenuous effort. now just about joining in as equal partners. A small handful of European firms are also now among the important semiconductor manufacturers, but there is no doubt that they gained this status by purchasing American firms and thus joining the semiconductor community on its home ground. The current leaders of the industry are listed in Table 1.

Another aspect of interdependence, true of industry in general but especially marked in the most advanced industries, is the dependence of each manufacturer upon a host of specialist suppliers. The manufacture of integrated circuits requires raw materials. chemicals, scientific instruments. optical and mechanical equipment and many other advanced items of great sophistication. In order to keep up with developments, the manufacturer must be in constant dialogue with his suppliers—a two way traffic of ideas and possibilities. An industrial system is in fact just that—a network of interconnected units each dependent on many others. This aspect of industry makes industrial development much harder, particularly in the most advanced industries.

Although all the glamour seems to be in the manufacture of the most sophisticated integrated circuits. much of the business is still in more technologically 'stable' discrete components and integrated circuits with few components. The market for discrete components is quite substantial and their manufacture is also becoming more sophisticated. Nonetheless. this is the simpler part of the business and might still be accessible to new entrants. especially if these were aided by some protective measures.

On the whole, it seems quite clear that to enter into the manufacture of very highly integrated circuits is

table 1

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company

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Toshiba
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Intel
Siemens[2]
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table 1

Shares of world semiconductor markets of 19 largest companies, excluding captive production, 1978

company	*base*	*market share %* all semiconductor	*market share %* integrated circuits
Texas Instruments	US	10.5	13.1
Motorola	US	7.8	6.4
Philips[1]	Netherlands	7.8	7.3
Nippon Electric	Japan	5.8	5.8
Hitachi	Japan	5.8	5.0
National Semiconductor	US	4.8	7.1
Toshiba	Japan	4.4	3.7
Fairchild	US	4.1	4.9
Intel	US	3.4	5.8
Siemens[2]	Germany	3.3	2.0
Matsushita	Japan	2.9	1.7
RCA	US	2.7	2.5
ITT	US	1.9	1.4
Mitsubishi	Japan	1.7	1.4
American Micro Devices	US	1.5	2.5
Thomson CSF	France	1.5	0.6
Mostek	US	1.4	2.4
Fujitsu	Japan	1.4	1.8
General Instrument	US	1.4	1.4
Collective share of world market		74.1	76.8

[1]including Signetics in US
[2]including Dickson in US

Source: *Dataquest*, 19 February 1980

just about the most difficult and least effective way of entering industrial production. The dice are loaded against the newcomer with a small home market, short of capital, short of skilled manpower and rich only in unskilled labour. The disadvantages become less formidable as one goes down the scale from massive integration, to special purpose integrated circuits, to discrete semiconductor components. But if less formidable the going is still tough, and the rest of the electronics industry may provide better opportunities than active semiconductor components.

Consumer electronics

The consumer electronics industry uses electronic and other components to assemble electronic goods for final consumption by a mass market, eg radio receivers, television receivers, pocket calculators, tape recorders. By its very nature, this industry does a lot of assembly work which can be quite labour intensive. The range of components a manufacturer produces internally as opposed to buying in can vary greatly, and the degree of sophistication of the products also covers a wide range, from simple radios to complex video recorders. Clearly a domestic industry can start from almost pure assembly of simple equipment—achieving mainly import substitution and some employment—and can gradually build up expertise to widen the range of both home produced components and final products.

With the right policies, giving high priority to training and a gradual shift from assembling foreign parts to truly home based manufacture, the consumer electronics industry can go beyond mere import substitution to genuine industrial development. The value added in this industry consists, at least in large part, of relatively simple operations, whereas in semiconductor manufacture, value is added almost entirely in complex processes. In consumer electronics there are many degrees of choice—from simple assembly of simple products to full manufacture of components and the assembly of elaborate products. Ready access to a substantial home market is a further point in favour of consumer electronics as a starting point for an electronics industry.

Industrial electronics and computers

Much that has been said about consumer electronics applies to industrial electronics. The range of products in this sector is very large, but assembly plays a substantial role in the production process. The main difference between the two sectors lies in the market—while one caters for personal consumption, the other caters for industrial users. Clearly, the latter market depends on industrial needs, and marketing can only be done by very close contact between potential user and potential supplier. In fact the industrial electronics sector is typically part of the industrial user supplier system, which depends on close links and a good flow of information. The success of an industrial electronics sector thus depends not only on what other industry exists, but also on the level of cooperation between the electronics sector and the other industrial sectors.

As process control and other industrial applications of electronics depend on the use of microprocessors, which can be bought quite cheaply on the world market, technical success depends on clever design of software and on sensors, actuators and system engineering. The production of application specific software is one of the cornerstones of industrial electronics. and competence in it can bypass the need for very specialised components. Training in systems engineering and programming are thus essential ingredients in the development of an indigenous industrial electronics sector.

The computer industry has become an almost separate sector, and it too spans a very wide range of products. There are the industrial giants producing large, very expensive and very sophisticated mainframe computers. This industry is almost comparable to the aircraft industry—only a very few international giants can supply all the needs, and competing with them is quite impossible. On the other hand, there are now hundreds of small manufacturers producing very small and often very simple computers ranging from the consumer-oriented home computer to the more sophisticated machine aimed at the small business. In between is a range of medium-sized computers used in larger office applications, in industrial control, in distributed modes where several smaller computers add up to quite a large installation, in scientific work and in many other ways. The rules of the computer would seem to be that today's smaller machine can do what yesterday's larger one could, but at very much lower cost.

From this, it would appear that entry into the computer industry is really only possible at the lower end of the market. At that end, a few clever systems designers and programmers can go a long way towards a viable product. The production consists largely of assembling bought-in parts, with only a few specially fabricated for the particular application.

Before leaving the electronics industry itself to discuss the implications of electronics for the performance of other industries in world markets, the question of 'strategic dependence' must be raised. It has been argued that any country aspiring to the status of an industrial power must have its own capability for the manufacture of semiconductor devices, including very large scale integrated circuits. This argument is based on the assumption that the semiconductor industry is fundamental to all other industries because semiconductors lie at the heart of electronics, and electronics is at the heart of much modern equipment and machinery. The argument goes on to assert that no country can afford to depend on any other for the supply of something as vital as semiconductor devices because supplies might be cut off and because domestic design becomes dependent on crucial foreign inputs.

There are numerous counter arguments to making semiconductors the cornerstone of a strategy of industrial independence. For although semiconductors may be seen as fundamental, they are not a good foundation on which to build industry. The industrial and economic system of any country is linked in multiple ways to the world economic system, and it is hard to see why dependence in the semiconductor area should be worse than dependence in any other—energy, metallurgy, plastics, pharmaceuticals, food, machine tools. In any case, the semiconductor industry itself is dependent on a vast variety of inputs, from silicon crystals to advanced photographic chemicals to computer-aided design. It would verge on the fantastic to believe that any small or medium country could build up the full range of industrial and service facilities required to run a modern, self-sufficient semiconductor industry. In any case, it is no more likely that the world market in semiconductors should become closed to any particular country than that any other market should become closed. Why should it be more acceptable to depend on the world market for chrome, or paper, or penicillin, or fighter planes, than for integrated circuits?

Microelectronics in industry

Microelectronic devices, that is integrated circuits and associated electronic components forming compact devices for the performance of a variety of tasks, have spread into many uses. The main functions performed by such devices are the storage and manipulation of information. Information may consist of anything that a suitable transducer can transform into a series of electrical signals. Thus the values of physical and chemical variables, such as specific gravity or temperature, may be regarded as information; details of an engineering drawing may be stored as information; and so. of course, may verbal or numerical information. Because the manipulation, storage, display and transmission of information is an important economic activity in itself and also underlies activities such as manipulation of materials, control of processes and shaping of artefacts, microelectronic devices have penetrated into a wide range of economic activities.

We use computers of all shapes and sizes, from mainframe universal computers to specialised applications of microprocessors, to handle office information and administration data, to control machine tools, to control robots for the handling of materials or tools such as spot welding guns, in telephone exchanges, in process controllers from chemical plant to domestic central heating. Perhaps the lumping together of so many varied applications of microelectronics in a short paragraph may serve to highlight two essentially different features of the technology: —it can save labour in labour intensive occupations in handling and assembling materials or information, and it can enhance the performance and quality of some products.

Clearly. labour saving is advantageous only if an overall saving in cost is achieved or if there is a particular shortage of labour. Such a shortage may exist even when there is no general shortage, and may concern some particular skills, or the unwillingness of labour to perform some unpleasant task. In general, the labour saving capability of microelectronics will rarely give a strong competitive advantage to developing countries. In fact the reverse is true: labour saving by electronics in advanced countries may erode the competitive advantage of cheap labour in some activities in developing countries. Occasionally labour saving is so great that it makes a task possible which previously might have been virtually impossible. This applies mainly to the capabilities of large computers to sort and sift large quantities of information which would defy an army of clerks.

The enhancement of the performance and quality of products is the one aspect of microelectronics which nobody can ignore. If, for example, the engines in some motor cars are electronically controlled and this improves their performance in a cost effective way, then after a short time no manufacturer of car engines can remain in an internationally competitive business without achieving comparable performance at similiar cost. The substitution of electronic controls for electromechanical devices in telephone exchanges, typewriters and process controllers of all kinds falls into the same category—a superior technology at advantageous cost cannot be ignored without erosion of competitive position.

Comparative advantage

The crux of any industrial strategy must be comparative advantage. But because comparative advantage depends upon particular circumstances of time and place, only very broad generalisations are possible and detailed decisions must vary from place to place and time to time.

Multinational corporations can often be induced to place some parts of their manufacture of semiconductors and electronics in developing countries. This can be worthwhile if it provides employment and foreign exchange, but it can be infinitely more worthwhile if it also provides a training ground for skilled labour and promotes further economic development by local purchases of supplies and services. The degree of off-shore involvement of the corporations varies from time to time, as the labour intensity of processes changes and with economic incentives on offer. Currently, automation in the production of semiconductor devices seems to be increasing and therefore the scope for off-shore activities is decreasing. For discrete components and electronic equipment the situation is somewhat different and there is scope for investment by multinational corporations. The benefits from such investment are undoubtedly subject to local policies and circumstances.

Developing countries have the advantage of cheap and willing labour, and this can be an incentive for locating relatively labour intensive operations. Whether such operations are financed by foreign or home based corporations, the main economic benefit to a country must come through training and infrastructural developments. This is why the advantages of consumer and industrial electronics were stressed earlier. For in these industries it is possible to take advantage of labour intensive assembly, and yet build up expertise in electronics and gradually increase the domestic component in the total value added.

As comparative advantage is so specific to time and place, the only principle that can be enunciated is the need to seek out comparative advantage and, as a corollary, to avoid comparative disadvantage.

The Asian Electronics Industry Looks to the Future

Jeremy Clarke and Vincent Cable

Introduction[1]

In recent years the electronics industry has become a considerable focus of attention for Third World policy-makers because of its apparent success in generating substantial employment and growth opportunities in a limited number of Asian and Latin American newly industrialising countries (NICs). It is the potential for imitating the successful experience of these countries that has attracted much interest and considerable policy effort by a group of poorer developing countries in South and South East Asia. These countries have attempted to foster an electronics industry by attracting foreign investment for the manufacture of components and assembly of consumer appliances, by encouraging the transfer of technology and by building up domestic infrastructure and skilled manpower.

However, it is clear that the circumstances in which these countries have embarked upon this road are significantly different, in that policy-makers in the industrialised countries are becoming increasingly sensitive to increased import penetration both from Japan and from less developed Asian countries [Cable and Clarke 1981]. In Britain, quota action has been used against Taiwan and South Korea to obtain 'voluntary export restraints', and Thailand is the latest country to be faced with restrictions (in black and white TVs).

The main aim of this article is to assess likely future developments both for the more advanced NICs and for the group of poorer Asian developing countries. One essential (though difficult) component of any 'future-gazing' in this industry is the need to assess the likely impact of future technological change. The most significant problem facing the more advanced NICs (especially South Korea and Taiwan) in this area is the extent to which they will be able to improve productivity and product quality through the introduction of automation, both in the production of components and in the assembly of consumer items. Whether these countries are capable of achieving such targets will largely determine whether they can reverse the emerging trend by which industrialised countries have attempted to forestall the otherwise predictable drift of production capacity to ldcs, by encouraging similar technological improvements in their own firms.

[1] In this article the 'Asian electronics industry' is taken to include South Korea, Taiwan, Hong Kong, Philippines, Singapore, Indonesia, Malaysia, Thailand and Sri Lanka. The larger economies such as China and India, which have adopted different development strategies for their electronics industry than that typically adopted in the countries named above, are excluded.

The character of the Asian industry

As Table 1 shows, the four South East Asian NICs (South Korea, Taiwan, Hong Kong and Singapore) continue to dominate exports of electronic products from all developing countries, accounting for nearly 80 per cent of all exports in 1978. Moreover, this dominance is growing, despite substantially increased exports from Mexico and Brazil during the 1970s and the extremely rapid growth displayed by newcomers such as the Philippines, Malaysia and Thailand. In fact sustained high growth by the four NICs has meant that their share of ldc electronic exports has increased from 60 per cent to 80 per cent during the years 1967-78.

The most obvious explanation for the spectacular performance of the NICs is the comparative success of a development strategy based upon the attraction of foreign direct investment by mainly US and Japanese multinational electronic companies in the components and consumer appliance industries. These companies were originally attracted by the lure of low labour cost production sites (particularly in South Korea and Taiwan) as well as a generous range of investment incentives.

In strong contrast, most South American countries (eg Brazil and Argentina) and India were less concerned to boost exports of consumer products than to establish a more selfreliant and broadly based electrical engineering industry. The industries of these countries have instead been characterised by restrictions on foreign ownership and the free flow of imported inputs [UNCTAD 1978]. The Asian industries owe much of their present character to the form MNC involvement has taken. Initial investments during the

table 1

1) Singapore
2) Taiwan
3) Korea
4) Hong Kon
5) Mexico[a]
6) Malaysia
7) Yugoslavia
8) Brazil
9) India
10) Thailand
11) Argentina
12) Indonesia
13) Philippines
total
(1-4) as % of to

Source: *UN Yea* electrica

Notes: * 1977 **
[a]Mexican

1960s and early 1 and wholly owne market. Two typ The first was th into consumer ap and, later, mono investments were as RCA in South assembly of colo was soon follow MNCs, who in production bases avoid the threat c sourced produc markets.

A similar pattern particularly follow companies of in Companies such Semiconductor w low labour cost process for sem packing) which highly depende investments in t

table 1

Growth of exports of electrical machinery from developing countries (SITC 72)
(US $ mn)

	1967	*1973*	*1976*	*1978*	*average annual growth 1967-73 %*	*output growth 1976-78 %*
1) Singapore	18.5	387.8	885.2	1568.4	66	77.2
2) Taiwan	38.6	741.8	1194.7	1487.0*	64	24.5
3) Korea	7.4	312.5	805.6	1252.2	87	55.4
4) Hong Kong	108.9	583.7	990.8	1228.9	32	24.0
5) Mexico[a]	13.6[a]	(410.5)	(723.6)	na	76	na
6) Malaysia	2.4	11.3	206.4	524.7	29	155.45
7) Yugoslavia	80.8	240.5	351.6	417.0*	20	18.6
8) Brazil	5.4	87.1	202.7	346.5	59	70.9
9) India	na	31.4	85.3	102.7	—	20.4
10) Thailand	0.4	1.8	48.0	64.8*	29	35.0
11) Argentina	2.9	32.9	37.0	47.4*	50	28.1
12) Indonesia	—	—	31.6	32.6**	—	3.2
13) Philippines	—	2.2**	6.4	25.9	—	304.7
total	285.7	2873.7	5653.2	7200.8	—	27.5
(1-4) as % of total	60.7	70.5	68.6	76.9	—	—

Source: *UN Yearbook of International Trade Statistics,* 1978 and P. Plesch, 'Developing countries' exports of electronics and electrical engineering products', *World Bank Working Draft,* table 5.

Notes: * 1977 ** 1974
[a]Mexican exports have been modified to reflect border assembly industries. Figures in brackets are estimates.

1960s and early 1970s took the form of direct investment and wholly owned subsidiaries producing for the world market. Two types of product and activity dominated. The first was the assembly of imported components into consumer appliances such as radios, tape recorders and, later, monochrome and colour television. Major investments were made by American companies such as RCA in South Korea, Taiwan and Singapore for the assembly of colour TVs for the US market. This lead was soon followed in the early 1970s by the Japanese MNCs, who invested in order to create major production bases in South East Asia for export and to avoid the threat of rising protectionism facing Japanese sourced products in major industrialised country markets.

A similar pattern emerged in the component industry, particularly following the mass production by American companies of integrated circuits in the early 1970s. Companies such as Texas Instruments and National Semiconductor were anxious to take advantage of the low labour costs in those parts of the production process for semiconductors (assembly, testing and packing) which were labour intensive. Despite the highly dependent form of such specialisation, investments in the component industry have nevertheless been largely responsible for the growth of employment and exports in Malaysia and the Philippines.

However, there were important technological differences between these two branches of the industry which have considerably affected the type of ownership and degree of involvement with foreign companies. In the consumer electronics sector there is a range of products (portable radios, tape recorders and black and white TVs) in which product design has become fairly standardised, and as a result technological change through product and process innovation has become incremental rather than fundamental. It has therefore been possible for nationally owned producers to emerge first in the NICs and now in a wider group of Asian countries. This has usually occurred with active participation by the MNCs whether through joint ventures (as in South Korea) or licensing (including Original Equipment Manufacturers (OEM) arrangements in which exports are marketed under the brand name of a Western manufacturer). There is evidence also of a gradual building up of domestic sources of supply for the major components required by the assembly industry.

The process has gone furthest in South Korea, Hong Kong and Taiwan with the emergence of large indigenous producers of consumer electronic appliances such as Samsung, Goldstar, Tatung, Radofin and Timco. Most of these started manufacturing under licence to MNCs, but increasingly the majority of their earnings come from products of their own design sold under their own brand names both in the Asian region and in Western countries through independent importers or direct to retail stores. The larger Korean firms such as Samsung now provide nearly all of their component requirements from domestic sources, including the more technologically advanced components such as semiconductors and colour cathode ray tubes. The largest firms have substantial R and D departments.

These are exceptional, however, and most producers even of the standardised items have links with MNCs, especially the Japanese. The role of the Japanese companies in providing technological know-how to the NICs has been somewhat ambivalent, since although they were apparently willing to assist the development of standardised or 'mature technology' products such as simple audio equipment and monochrome TVs, for commercial reasons they have tended to keep a much tighter control of technical know-how in more advanced products and processes where technology has been changing more rapidly. It has also been claimed that Japanese producers of essential components such as colour cathode ray tubes have even in some instances withheld supplies in order to provide a commercial advantage to those NIC firms with technical co-operation agreements with the Japanese. The pattern of Japanese involvement in Asia has therefore been mainly to build up production of standardised technology products. However, apart from the largest South Korean and Taiwan firms, the price of reliance on Japanese companies for know-how in consumer electronics has been a heavy dependence on Japanese sourced component supplies:

> Asian nations are now established as the supply base of consumer electronic appliances for the world . . . they are nevertheless heavily dependent upon Japan for supplies of integrated circuits, precision component parts and colour TV components. They import more than 70 per cent of their needs from Japan.
>
> [*Journal of the Asian Electronics Union (JAEU)*, July 1981].

Despite the successes of the South Korean and Taiwan industries and the introduction of restrictions on foreign investment in recent years, it is clear also from Table 2 that foreign involvement is still substantial in these countries, at around 45-50 per cent of total production. Levels of foreign ownership are even higher in the second ranking group of Asian producers, with levels of over 90 per cent being the norm. The same is true of Singapore, where over 80 per cent of production is by wholly owned subsidiaries of MNCs (mainly Japanese but now also European).

Dependence on MNCs is even higher in the case of technology intensive components such as integrated circuits and microprocessors, where the product life cycle is short and rates of innovation high. In general it has been extremely difficult for Asian countries to develop a domestic production capability in this sector, partly through lack of know-how but also due to high rates of innovation which render such components obsolete within a short space of time. Nevertheless, there are examples amongst the advanced NICs where locally owned firms have emerged or additional foreign investment made as a result of linkages to MNC component makers. Moreover, as some Hong Kong firms have shown, assembling advanced technology components can have its benefits, since locally available components can be used to design brand new products. For example, Hong Kong's recent 'miniboom' in the production of hand held electronic games was largely the result of the fact that in 1977 several US firms set up offshore processing facilities for the construction of microprocessors which were assembled from kits imported from the USA. At first many of the locally owned firms such as Radofin worked on a sub-contracting basis, but they soon diversified into other product areas using the available supply of micro-processors to produce a host of advanced technology products, including electronic watches, printing calculators, teletext adaptors, viewdata receivers and video games. Firms such as Radofin have shown a considerable capacity to combine locally available components with in-house design skills and sub-contracting deals which have given access to technically advanced products. The company has in fact recently developed its own viewdata receiver manufactured to British Telecom standards and capable of converting any PAL[2] TV set into a viewdata terminal, at a price below most of its competitors. Other Hong Kong firms have been designing and making automatic language translators and producing some of the latest products such as programmable calculators.

Future prospects for electronics in Asian ldcs

The future development of electronics in Asian ldcs depends partly on internal factors and national policies but, as we have noted, the industry is still so heavily export orientated and dependent upon foreign capital that much also depends on external factors over which governments may have little control. Enough

[2]PAL (Phased Alternating Line) is the main transmission system operating in Europe.

table 2

country
South Korea
Taiwan
Hong Kong
Philippines
Singapore
Indonesia

table 2

Characteristics of the Asian electronics industry c. 1980

country	*pro-duction ($ mn)*	*composition*	*%*	*dependence on exports (exports/ production %)*	*number of workers '000*	*dependence on foreign investment*	*stage of development*
South Korea	3,300	consumer appliances industrial appliances components	40 10 50	70	180	25% (50% including joint ventures)	export base for consumer electronic appliances and components
Taiwan	3,200	consumer appliances industrial appliances components	45 6 49	80	230	45% (including joint ventures)	export base for consumer electronic appliances and component parts
Hong Kong	2,000	consumer appliances industrial appliances components	68 2 30	more than 90	90	approx. 10%	export base for low-to-medium priced consumer electronic appliances
Philippines	320	65% components otherwise mostly for consumer appliances		90	34	extremely high	export base for components, and assembly base for electronic appliance for local market
Singapore	1,850	consumer appliances industrial appliances components	39 2 59	90	66	extremely high (more than 80% of total production)	export base for consumer electronic appliances (dependence on imported components more than Korea and Taiwan)
Indonesia	541	more than 90% for consumer appliances		2	43	high (foreign investment is restricted to some areas but most producers are receiving technical assistance)	assembly base for electronic appliances for local market

continued

table 2 continued

country	*production ($ mn)*	*composition %*	*dependence on exports (exports/production %)*	*number of workers '000*	*dependence on foreign investment*	*stage of development*
Malaysia	990	90% components	75	61	extremely high (more than 90% of the total production)	export base for low-to-medium consumer electronic appliances and some components
Thailand	106	90% consumer appliances	10	40	extremely high	assembly base for electronic appliances for local market
Sri Lanka	little	small production of radios	—	na	low	assembly base for some electronic appliances for local market

Source: *Journal of the Asian Electronics Union*

has already been said to indicate that the Asian industry can be usefully divided into two distinct categories (excluding the large and more self contained economies of India and China). The four NICs represent one group in which sizeable national firms have emerged in an industry which has proceeded some way toward technological independence and high local sourcing levels in at least some products. The second group is composed of a growing number of technological 'followers' including Malaysia, Thailand, Indonesia, Philippines and now Sri Lanka. As Table 2 shows, this group of 'followers' is characterised by a very high degree of dependence on foreign investment, and where exports are significant (eg Malaysia and the Philippines) they are mostly of components such as integrated circuits and other semiconductors.

The 'followers'

All of these countries are still at the stage of assembling consumer appliances from imported components predominantly for the domestic market, but they have reached different stages in the process of building up local content levels. Moreover, some of these countries have also established a significant export trade in the component sector.

Malaysia, and to a lesser extent the Philippines, have managed to build up substantial employment levels of 61,000 and 34,000 respectively by concentrating upon the export of integrated circuits which for the most part have been produced by MNC subsidiaries in Free Trade Zones with few linkages to the domestic economy. The concentration on increased exports and employment is also noticeable in the consumer appliance sector in the emphasis on production of simpler technology products such as radios and radio cassette recorders, whereas TV production is negligible.

Indonesian development has largely been confined to the production of consumer appliances for the home market, but there is an emerging export surplus of more advanced products such as monochrome and colour TVs. Thailand is also starting to export consumer appliances, including TVs, from an industry hitherto based on home demand. The Thai industry has, moreover, been growing rapidly, but dependence on imported components remains high (it is estimated that only about 10 per cent of value is added locally). Nevertheless the scope for domestic entrepreneurship seems wide and there are currently seven large-scale radio and TV factories, 20 small-scale assemblers and a growing 'cottage industry'—radio repair shops and wholesalers who assemble and market copies of popular models. It is claimed that nearly a third of domestically owned radio sets are purchased in this way.

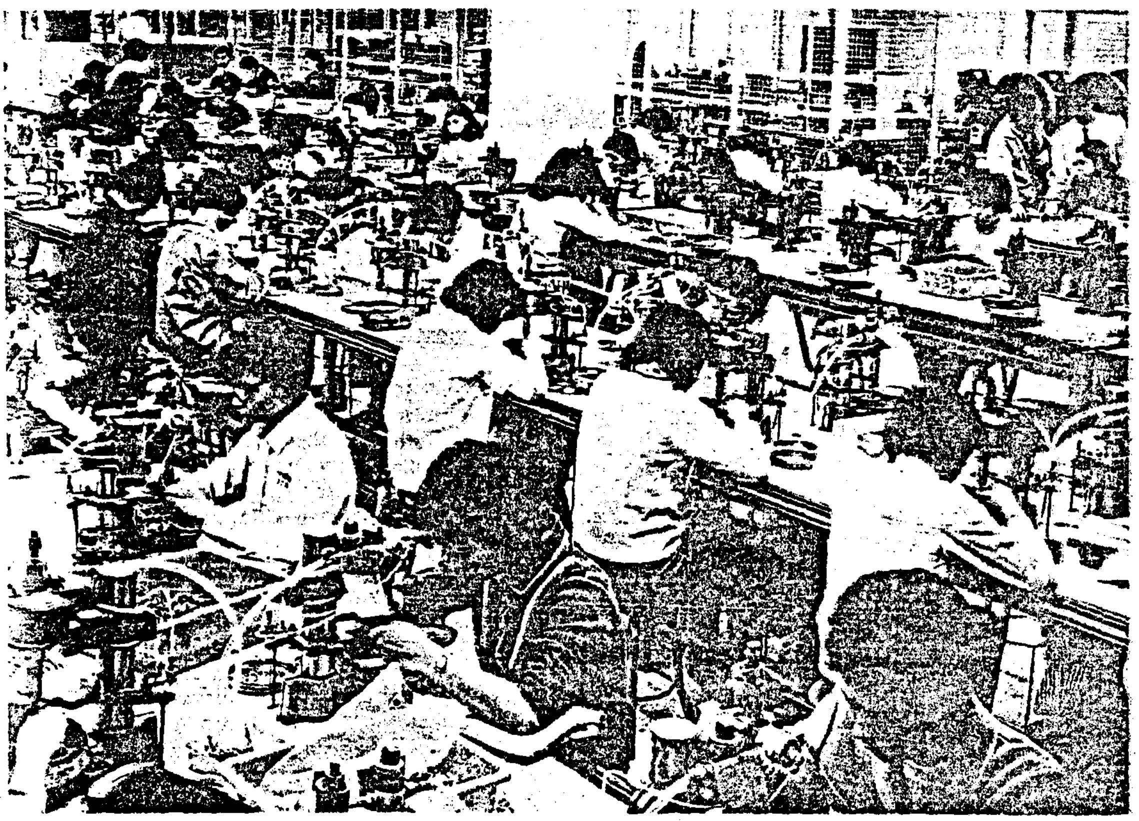
A common aim of many of the governments of these countries is to promote the expansion of the consumer appliance sector because of the scope for gradually increasing the share of components coming from nationally owned producers, whilst at the same time maximising the technological spin-offs from foreign capital investment. for example, in Thailand,

> the government through the Board of Investment has placed the electronics industry on its priority list for production privileges because it recognises that the industry is export orientated, labour intensive, uses advanced technologies and provides linkages with a wide range of other activities.
>
> [*JAEU*, February 1981]

The Philippine Government in particular has also embarked on a large-scale education programme designed to provide specific engineering skills to the growing industry. However, the building up of the consumer appliance sector in these countries remains highly dependent on Japanese firms, most notably in the more technologically advanced products such as TVs and music centres.

The four NICs

Governments of the four Asian NIC producers have several interrelated objectives for the future of the electronics industry; to achieve higher value added, improved quality and more diversity in their product range; to reduce labour intensity in the production process (because of emerging labour shortage); to develop a capacity to produce the latest and most sophisticated products and to carry out a greater degree of R and D domestically. Clearly the extent of government involvement will vary considerably from the more 'organised' and 'dirigiste' approach of South Korea to the more entrepreneurial style of Hong Kong, with the other two countries somewhere between these extremes. Korean firms (with government backing) plan ahead and then embark on large-scale production of relatively new but well defined product areas, with as much local technological and material content as possible. Hong Kong's flexible and adaptive businessmen, on the other hand, have been more successful in anticipating and responding to shifts in fashion, but have been less concerned to build up the supporting infrastructure and linkages for large-scale



Information Service, Taiwan Authorities

Examination of electronic components.

industrial production ('speculators rather than investors' as they have been described).

Based on their past performance, the capacity of the NICs to achieve their objectives is likely to be varied. In fact. South Korea and Taiwan have gone furthest towards formalising and achieving their stated objectives. In the past, priority has been given to reducing dependence on imported components which are often in short supply (and may be deliberately withheld in some cases) and at the same time to reduce their role as exporters of specialist semiconductors. In the consumer appliance sector South Korea and Taiwan now provide nearly all of their component requirements from local sources (Korea now has 85 per cent local components in its colour TVs). Even components such as semiconductors and colour cathode ray tubes, which were until recently imported exclusively from Japan, are now being produced by large indigenous firms like Samsung and Tatung. Korea has also managed to reduce its dependence on components by cutting the share of these products in the total value of electronics exports from over 80 per cent in 1970 to well under 50 per cent. Less organised Hong Kong remains more dependent, and manufacturers of consumer appliances typically import around 60 per cent of their component needs.

The future objectives of the NICs are reflected in the forward plans and policy statements made by their governments. For example, South Korea has recently announced a 'Basic Plan for Promotion of the Electronics Industry'. According to the Chairman of the Korean Electronics Association the main aim is to 'foster development efforts in order to achieve the automation of production facilities, the improvement of product quality and the development of new products' [*JAEU*, July 1981]. The Plan calls for the rationalisation of existing production facilities for consumer appliances such as TV and audio equipment and for the establishment of domestic production of video cassette recorders (VCRs) and video discs. In tandem with this it is recognised that product quality must also be improved, and the latest technical advances are taken account of in a whole range of consumer appliance components, including coloured cathode ray tubes. silicon wafers, liquid crystal displays and high density printed circuit boards. The Koreans have also placed particular emphasis on the development of more advanced technology products including semiconductors. computers, computer peripheral and terminal apparatus, and the development of Very Large Scale Integration (VLSI).

A similar approach has been adopted by the Taiwan government. which is also attempting to promote technology intensive operations by providing government assistance for R and D. This is designed to improve production techniques, to develop new products and to provide quality testing equipment.

Even in Hong Kong, whose authorities have been less actively involved, it is officially recognised that there should be an effort to increase product and process innovation, and efforts are being made to 'concentrate on skill and technology intensive operations and to pay more attention to manpower training and the provision of adequate support facilities' [Hong Kong Government 1979:13]. The Hong Kong authorities have also encouraged businessmen to diversify into technologically advanced sectors such as microprocessor-based industrial control equipment, data processing and peripherals, and microcomputers, as well as a new generation of components (large-scale integrated circuits, high reliability printed circuit boards, connectors and interconnection systems).

The objectives of the NICs suggest that in the future they are aiming to combine the advantage of relatively low labour costs with more advanced technology in the production of consumer appliances and components. In the range of existing products this implies 'capital deepening' technical innovation involving in this case the increased use of automated machinery in the production process. In the consumer appliance sector it is in the production of colour TVs that the major technical advances have been made, so far mostly by Japanese firms. The introduction of automatic insertion equipment in this sector is also linked to improvements in product design which have tended to reduce the number of components per set.

If NIC firms were able to adopt the best Japanese practices this would tend to reduce the labour component in set production and encourage the adoption of more capital-intensive automated production techniques which would simultaneously improve product quality and overall cost competitiveness. In this way they would keep one step ahead of both Japanese exporters and industrialised countries like Britain, which are trying to stay in the colour TV business by adopting Japanese production techniques.

However, despite the success of large NIC firms in recent years, their ability to carry out such far-reaching reforms from their own resources is likely to be limited. Most of the larger Asian companies have their own R and D divisions, but their capabilities and the extent of these resources should not be overstated. For example, in terms of product and process technology it has been claimed that South Korea is trailing 15 years behind Japan, and the gap may be widening, since R and D expenditure of Korean firms is put at only 1.3 per cent of sales revenue, a third of Japanese levels [*Economist*, 6 September 1980:68].

The achievement of government objectives in this sector seems to imply the necessity to forge technical cooperation deals with the most advanced (Japanese) firms (both consumer appliance and machine makers). In Korea it is hoped that this can be done by acquiring licences involving the payment of royalties which generally range from three to four per cent (but may be as high as 10 per cent) of the product selling price.

Although these policies have proved successful in more standardised areas of product and process technology, it is apparent that Japanese firms (even in the case of joint ventures) have displayed a reluctance to sell licences for more advanced technology. As Scibberas [1979] has pointed out, Japanese firms prefer to transfer know-how only for 'simple products such as black and white sets and simple colour portables, using older technology in tubes and semiconductors'. The same is apparently true of innovations in process technology since 'with the exception of subsidiaries of some Japanese firms all assembly in the developing countries was done manually'. Japanese producers have also been unwilling to provide Korean firms with technical know-how for new products such as VCRs and video discs.

Nevertheless, despite the apparent reticence of Japanese firms to provide advanced technical expertise, another source may be European consumer electronic firms which are showing increased interest in NIC production sites as they undergo considerable restructuring in the face of severe Japanese competition. For example, Philips has recently declared:

> we would like to be able to close some of these (European colour TV plants) and concentrate production in one or two locations and if need be move production to cheap locations offshore (eg in the Far East).
>
> [*Economist*, 28 June 1980]

In fact, the expansion of colour TV exports to Europe by Asian countries has been severely restricted in the past by the PAL system of patents which effectively prevented non-licensees from exporting larger screen sizes to Europe.[3]

However, the protective effect of the licensing system will decline as the licences begin to expire in 1982-83 and as more companies are granted licences. As yet only Japan and Singapore-based manufacturers have been licensed, but South Korean, Taiwan and now Thai firms are all currently negotiating on royalties and licensing. In fact, European firms seem to be increasingly willing to enter into technical assistance agreements with NIC firms and in some cases to engage in foreign direct investment. For example, Philips already has a portable colour TV factory in Singapore operating within the PAL licence system and as a result there has been a rapid export expansion to Europe (Singapore provided 12 per cent of all UK colour TV imports in 1979).

Thomson-Brandt also operates a wholly owned subsidiary in Singapore (European Standard Electronics) producing portables to PAL specifications. AEG/Telefunken has recently reached an agreement to produce colour TVs in Hong Kong for export to Europe, and had previously entered a technical assistance agreement with the Singapore firm 'Roxy Electric', which now produce colour portables to PAL specifications.

This increased involvement of European firms is likely to lead to improvements in local standards of product design and production technology, but it is increasingly apparent that NIC quality and design standards have been improving anyway. This has occurred in South Korea, where 'established makers of CTVs have plans to upgrade their product lines . . . by introducing new models with high end features', and in Singapore, where new models have fewer components and increasingly sophisticated optional features such as sensor touch switches, remote control devices and stereo sound [*Asian Sources, Electronics*, November 1980:10].

Over and above the difficulties involved in obtaining satisfactory collaboration with Japanese TV firms, there is an additional problem presented by the predominance of Japanese firms in the production of automatic insertion equipment (Matsushita Electric Industrial company is the main supplier in this field). Nevertheless, Universal of the USA is also a major producer and may be more willing to set up licensing agreements. Some machine makers have in fact experienced increased sales both to Europe and South East Asia (South Korea and Taiwan) [*JAEU*, July 1981].

There are also signs that at least in some South East Asian subsidiaries of major Japanese manufacturers the level of automation is increasing, where it is justified by sufficiently high plant volumes. For example, Hitachi Singapore (whose main markets are the USA, the UK and China) have embarked on an ambitious plan to double the level of CTV production to over 300,000 units per annum using computer controlled automatic circuit board assembly systems and component sequencing equipment.

[3] Companies wishing to produce sets for markets in the PAL system (ie Europe) are required to take out licences from the West German manufacturer, Telefunken. Eleven Japanese companies and some Singapore and Hong Kong based manufacturers have been granted the licence, but Korean and Taiwan firms have been excluded. However, Telefunken's main licence expired in 1980 and the rest of the PAL patents begin to expire in 1983.

The NICs also have ambitions to diversify their electronics industry into the production of advanced technology components, into new product areas such as computers and new branches such as industrial electronic testing equipment. It is possible to point to some successes in this sphere. For example, some Hong Kong firms are said to be capable of designing and producing sub-systems for computers, and some manufacturers have also demonstrated the capacity to design circuitries for sub-assembly components, to meet the requirements of overseas buyers. It is also apparent that the NICs have been moderately successful in building up backward linkages in the production of some of the more standardised integrated circuits (ICs). These have included crystal growing and circuit design, but also the production of connectors and interconnectors which are key components in microprocessors. There are at present only six plants in the world producing connectors and interconnectors, and the latest is being built by Dupont in Singapore. Other advances have been made by the major NIC consumer appliance manufacturers (eg Samsung), who produce nearly all of their semiconductor requirements in-house. A Hong Kong firm, Micro Electronics Ltd. is currently making silicon wafers for local production of integrated circuits, and two Taiwan firms are also making standardised ICs for use as memory chips in a wide variety of local consumer good applications.

Nevertheless, there are serious constraints on further advances in an area where technological change is so rapid and the R and D commitment by individual firms needs to be so great. This is likely to make future developments heavily dependent upon foreign investment and technical link-ups with leading firms. In fact, major progress still needs to be made in the development of an indigenous production capacity, even in standardised integrated circuits, and what has been said of the Hong Kong industry is generally true of the NICs as a whole:

> very few local companies are capable of producing these items [integrated circuits] from the basic material, silicon wafers, and most companies import completed wafers and perform assembly and preliminary testing operations.
>
> [Hong Kong Government 1979:10]

Future growth

Predictions of future developments in production and trade in electronics are far more speculative than in other product areas. Since Asian exports are heavily orientated towards the markets of the industrialised countries, the level of exports is generally highly sensitive to the level of overall demand in these markets. The nature and impact of technological innovation is also difficult to predict, as are the strategic interests of MNCs.

Nevertheless, we shall briefly examine three of the most significant determinants of future growth in this industry and in this range of products; the level of domestic consumption, the international trading environment and the effects of technological change.

Regarding the last of these, it is apparent that technological advances made in products such as colour TVs have made it possible for the industrialised countries to contemplate the possibility of halting or even reversing the previous trend towards increased ldc production in the consumer appliance sector.

By increasing the skill component and capital intensity in production of colour TVs these developments will clearly make it more difficult for the NICs and the 'followers' to compete because their comparative advantage still lies mainly in the production of electronic products of standard design and in labour intensive assembly operations. This obstacle is particularly large in the case of the 'followers', such as Thailand and Indonesia, who are attempting to 'trade up' into the production of colour TVs and other more advanced products. The NICs are likely to be less affected by these developments, provided that they are able to improve product design and quality and are capable of adopting 'best practice' (Japanese) production techniques. The product and process innovations that have been made by Japanese firms have significantly raised productivity levels as well as markedly improving product quality and reliability.

Until recently these technical advances had been mainly confined to Japanese firms, but it is increasingly apparent that European companies are attempting to emulate them. A measure of the technological lead of the Japanese companies is that in 1978 Japanese consumer appliance firms had an average of 70-80 per cent of all components automatically inserted in the production of colour TVs, compared to as little as 15-30 per cent in Europe and as yet negligible amounts in South Korea and Taiwan. Earlier research indicated that European countries are keen to restructure their domestic consumer appliance industries both by encouraging indigenous companies to upgrade products and automate the production process, but also (as in Britain, for example) by encouraging foreign direct investment by Japanese MNCs. The same is also true of component production where product quality and levels of automation are increasing in industrialised country plants.

The strategies of the Japanese companies are the main unpredictable element because the adoption of 'best practice techniques', either by the NICs or by industrialised countries such as the UK, is likely to be dependent upon their capacity to attract foreign direct investment and technical cooperation from these firms.

Unfortunately for the NICs Japanese firms seem to be increasingly turning their attention to the industrialised countries:

> in the past, Japanese producers directed their attention to Asian countries as a place for overseas production but there is now a move to divert investment to developed countries in North America and Europe ... no substantial expansion beyond the current fairly active situation is expected from Asian countries as production bases.
>
> [*JAEU*, July 1981]

One of the main reasons for this re-direction of footloose foreign investment from ldc production sites is increased protectionism in industrial country markets. This threat seems to have affected a number of investment decisions by Japanese companies but the same is increasingly true of the major Korean and Taiwan firms. For example, the Korean firm 'Gold Star' recently opened up a plant at Alabama, USA and other Korean manufacturers—Samsung and Taihan Electric Company—are contemplating producing colour TVs in Europe and the USA respectively. The Taiwan firm, Tatung, has recently acquired the Racal/Decca plant which was closing in the UK, and it now plans to produce monochrome and colour TVs for the European market.

Increased protection in industrialised countries also has a more direct effect by restricting demand from the industrialised countries for electronics products produced in Asia. Current restrictions take the form of non-tariff barriers (eg voluntary export restraints in the UK, orderly market arrangements in the USA) which enforce quotas, mainly against the NICs at present but increasingly also against other Asian producers. However, as they stand, restrictions mainly cover more technologically sophisticated products such as colour TVs and music centres, although in the case of the UK black and white TVs are also restricted. This is because pressure for protection is weaker in technologically simpler products like radios and tape recorders, production of which has almost disappeared from many industrialised countries, and whose former producers now have an interest in subcontracting or importing arrangements with ldcs. Although this seems to augur well for the 'followers', the advantage of relatively unrestricted market access has to be weighed against the fact that many of these products are in what has been called the 'mature phase' of the product cycle and face a relatively slow (or even declining) rate of growth of market demand.

The future of the Asian industry is also dependent upon increased demand in the home market, and market forecasts show that this will be a significant source of growth for some countries. Now that Korean firms have been freed to produce colour TVs for the local market, it is clear that domestic demand will form an important source of future growth. Most of the group of followers are predicted to experience growth in home demand, and in most cases this will be met by increased domestic levels of production. The growth of domestic production in this group is in part due to the increased willingness of NIC-based firms with interests in South East Asia not only to subcontract the labour intensive assembly phase of the production process, but also to engage in technical assistance agreements designed to build up local manufacturing capability and the level of domestically sourced components. Taiwan firms are particularly active in this way, and companies like Shinlee are involved in exporting monochrome TV manufacturing know-how, as well as key parts and components in the form of Semi-Knocked Down (SKD) or Completely Knocked Down (CKD) shipments to overseas factories in Thailand and Indonesia. Another company, Elan, has recently begun CKD shipments to Indonesia (for local sales and re-export) and also to India for the local market. The explanation of this trend seems to be that NIC companies wish to secure production bases in potentially large regional markets. If this is so then the future growth of production capacity in these countries is unlikely to result in increased exports to industrialised countries, and may also give rise to conflict with indigenous firms who do not have the advantage of such technical link-ups.

Conclusion

The prospects for increased exports of consumer appliances and components from the Asian NICs will be determined mainly by the extent to which current 'best practices' in product and process technology can be adopted either directly by NIC firms or in collaboration with the leading Japanese firms. Particularly in the consumer appliance sector, future trends in protection remain important, not only because trade barriers may be used to restrict exports directly but also because they create an incentive to redirect foreign investment to industrialised countries. The available evidence suggests that both trends seem to be working to the disadvantage of the NICs at present. However, to set against this, there are also some signs that the pressure of competition in the consumer appliance sector is encouraging some of the main European firms to consider production locations in the NICs. It is possible that such moves might ultimately redirect the attention of Japanese firms towards the expansion of Asian production sites.

In any event, a fairly optimistic picture is presented by the broadly based official predictions of the NICs. Korean official forecasts suggest that total electronics exports will reach $3 bn in 1981 (roughly six per cent of world trade) and the government is aiming for a 21 per cent average annual increase in the value of exports by 1986. Taiwan is keeping roughly abreast with Korea, and Hong Kong expects to provide 2.5 per cent of the world market by 1985. Although Korea and Taiwan are predicted to experience export growth in colour TVs—by 12.5 per cent and 6 per cent respectively during 1980-85 [*JAEU*, July 1981]—Singapore exports of colour TVs are predicted to remain static and exports of most other products from NICs are expected to decline. Amongst the 'followers' only Indonesia and Malaysia are expected to produce an exportable surplus, and production in Thailand, Sri Lanka and the Philippines remains geared to meeting domestic demand.

It is extremely difficult to draw any concrete conclusions from such patchy data, but based upon current trends in protection and technological change, it seems likely that it will be more difficult for the NICs to increase production and exports of electronics products in the future. It is also likely that it will prove more difficult for the 'followers' to reduce dependence on labour-intensive assembly activities in their attempts to move into the production of more technologically sophisticated products.

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allow full automation and dramatically reduce labour inputs. Private sector firms in the developed countries are expected to be the first to introduce these innovations. It is alleged that this would improve their competitive position *vis-à-vis* Third World producers and deprive developing countries of crucial export markets.

Given that the apparel industry shares some similarity with shoes, textiles and other labour intensive sectors, it was felt that a detailed examination of developments in the industry would provide valuable insights at a more general as well as at the specific level. In the next section we briefly review the nature of the production process (prior to the introduction of microelectronics) and some of the structural and institutional characteristics of the industry. Next, innovations in sewing technology containing microelectronics are described: while in the final section some concluding observations are presented on the implications of these changes for the Third World.

Traditional production technology

The manufacture of garments typically involves a sequence of activities where an operative is required at the interface between material and machine at each stage. (The discrete activities include: design, grade and cut pattern, plan optimised lay, lay and inspect for faults, mark, cut, label and bundle, transport to sewing station, assemble, inspect, press and finish, inspect, pack.) Although the basic steps in the process are the same for all garments, the tremendous variety of wearing apparel that is produced to meet the demands of the fashion-conscious consumer in the developed countries in fact imposes widely differing operating parameters from garment to garment. In some cases, such as jean manufacture, production runs are long. Only a relatively few pieces of material need to be sewn together to make the jeans, the sewing tasks are straightforward and style changes are comparatively few. In ladies' clothing, however, the situation is precisely the opposite: there are many style changes, short runs, complicated sewing tasks are required to accommodate design changes, and there are frequently many pieces to be assembled.

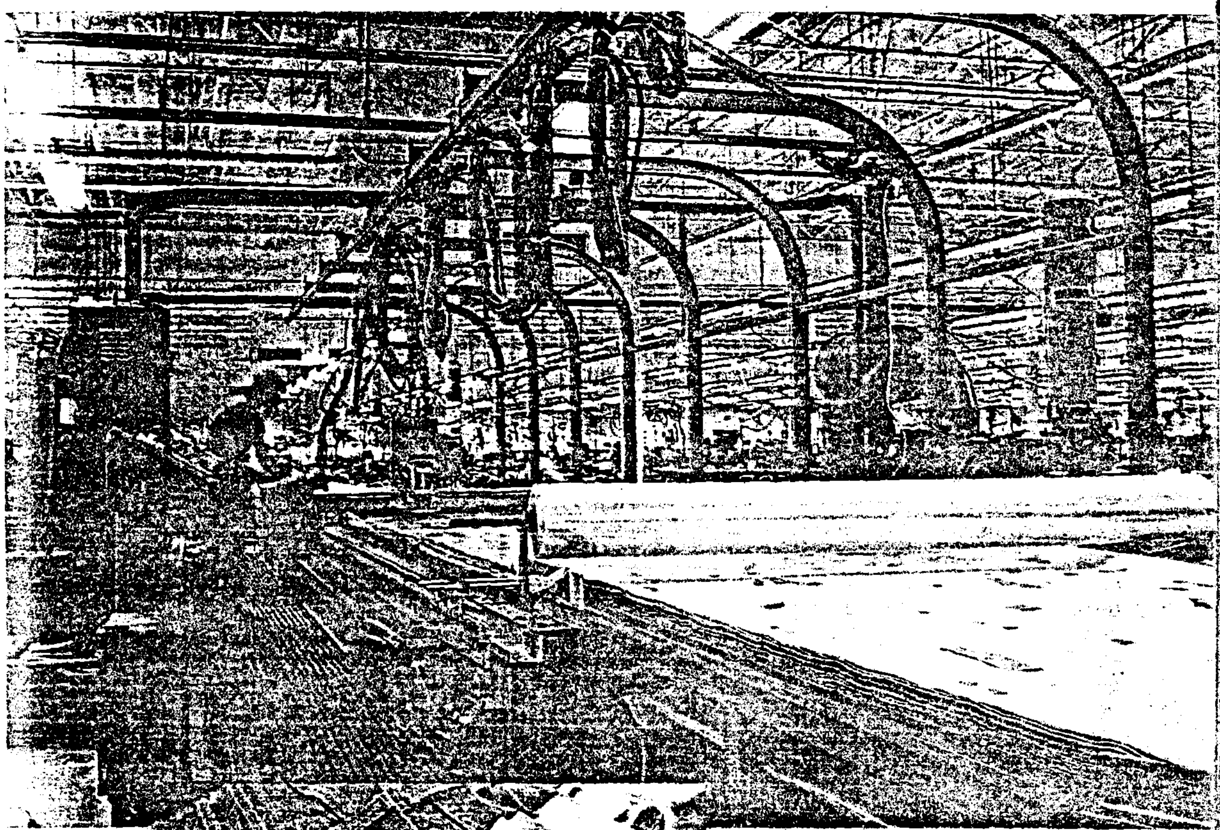
In the face of these conditions, the industry historically has relied upon highly skilled operatives and reliable, inexpensive, all purpose sewing machines which can be cheaply and quickly adapted to the different sewing requirements for each type of garment. The rate at which innovations have been introduced into the industry has been much slower than in other sectors. The basic sewing machine design, which still predominates, is almost identical to the industrial machines of 50 years ago!

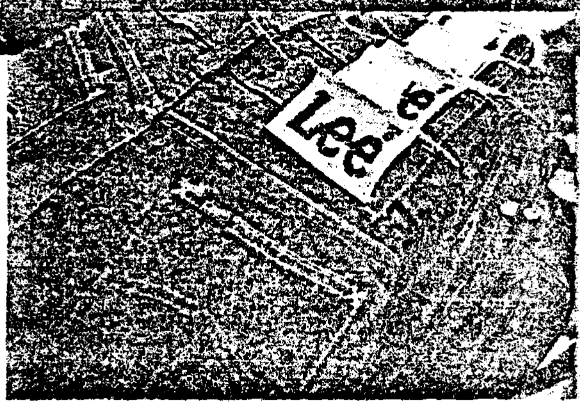
There are many reasons for this slow rate of technical change, the major one being the continuing ability of highly skilled manual operatives to respond quickly and efficiently to the technical demands of rapid style changes. However, there are other factors—the industry is highly fragmented, very undercapitalised and, apart from the large firms, is burdened with archaic management practices. Equally as problematic as these institutional obstacles are some significant technical barriers to innovation which centre around the problems of handling the 'limp' fabrics which make up garments. As we shall see, since the average rate of investment in R and D in the apparel industry is very low (about 0.05 per cent of sales) and the capital cost of overcoming these problems very large, prior to the advent of (micro)electronics there has not been much progress towards their solution.

As a result of these structural and technical characteristics of the industry in the developed countries, the level of technology in use by Third World manufacturers is roughly on par with that employed in the advanced industrial economies—certainly the gap between best practice techniques and the average production methods in use in developing countries is much smaller in the garment sector than in other sectors. Consequently, relative labour costs have been the main determinant of competitive position, although quality factors have so far prevented developing countries from competing internationally in some lines of apparel. Due to low wage rates, Third World manufacturers have enjoyed an increasing degree of comparative advantage in a number of high volume sub-sectors as wages have risen in the West.

Although technical change has, as stated above, been relatively slow in the industry, during the 1950s, 1960s and early 1970s the introduction of electronic controls allowed for continuous, if modest, increases in productivity for specific sub-processes now carried out by specialised machines. Due to the relatively high capital costs of these specialised machines, now costing thousands of dollars as opposed to the average cost of $600 for a standard sewing machine, the comparative advantage of less developed countries has remained intact. The differential in labour costs is substantial—with US 100, the UK 40, Japan 20, Hong Kong 10 and Taiwan and South Korea 5. This differential has remained so that a large number of international firms have located an increasing proportion of assembly in low-wage countries either through sub-contraction, joint ventures or wholly owned subsidiaries.

The introduction of microelectronics in the late 1970s raised the expectations of some observers, both inside and outside of the industry, that the formidable technical obstacles to automation would be removed. It was felt





Gerber Scientific Inc.

Computer aided pattern cutter used in manufacture of jeans.

that the microprocessor, with its vast information processing capacity and inherent flexibility had the capacity to facilitate radical technical changes at the sub-process and systems level.

While the changes that were widely predicted have yet to advance beyond the first generation of innovations, the awareness and interest of the industry in advanced industrial nations has certainly been captivated. Within the last three years the number of capital goods firms offering microelectronic controls in their sewing machines has increased from less than a half dozen to over 25. In addition, firms and individuals from outside the industry, who have extensive experience in electronics, have introduced the most radically new innovations in garment technology.

Microelectronics-based technologies

Below we briefly describe some of these innovations. There seems little doubt that these and subsequent innovations will eventually dramatically alter the structure and character of the industry in the advanced industrial economies. However. the rate at which this transformation will take place is still open to question. given the deeply rooted and inbred nature of some of the structural and institutional problems referred to above.

Grading. laying out, marker making. and cutting have traditionally been separate and highly skilled manual tasks. Given the value of the cloth in total costs of the finished product (often reaching 50 per cent). the phase of laying out patterns on the cloth is crucial if wastage is to be kept to a minimum. Likewise. cutting the cloth precisely according to the lay is equally important, particularly since error at this stage can lead to defective garments at the assembly stage. The sequence of tasks from grading through to cutting has been the only operation for which automation with microelectronics has significantly bridged the gap between what were previously discrete activities. Technology is now available that combines computerised pattern grading with optimal pattern layout. marker duplication facilities and electronically controlled cutting. Several firms. notably Camsco and Gerber in the United States and Laser Lectric in France offer a mini computer-based system which allows operators already skilled in traditional techniques to increase the speed of grading and laying out from two to six times—grading which previously took four days now takes only one hour—while simultaneously reducing waste from between two to five per cent. When the value of fabric usage runs as high as $10 mn as is the case in a number of medium sized firms. even a two per cent fabric savings is substantial considering the low profit margin per unit. The outright purchase of these systems. however. costs between $300.000 and $600.000 and necessitates maintenance contracts in the range of $1,800-$2.600 per month. Not surprisingly. the sizeable initial investment and the high fixed and running costs have led to the establishment of service bureaus which offer these services to users who cannot justify purchasing the systems themselves.

Cutting technology. having remained static until the early 1970s has moved from a manual technique using a hand held electrical or mechanical knife to completely mechanical cutting that is electronically controlled. A decade of experience has seen the virtual demise of automatic dye cutting. as well as the use of lasers and high speed water-jets to perform cutting. These have largely been superceded technically by the Gerber computer controlled cutter. which incorporates a self sharpening blade. This machine, which requires complete re-engineering of the cutting room to attain maximum efficiencies. costs around $600.000-$1.000.000 and employs the programming facilities offered by the Camsco or Gerber marker makers described above. This has greatly reduced the time involved in these phases of the process from about one hour to a (maximum) of four minutes per suit. Skilled labour input is reduced dramatically with savings of up to 1000 per cent reported by some firms in their marking and cutting workforce.

Although technologically impressive, these innovations are associated with activities which give only limited increases to value added. And given the high level of investment required these can only be afforded by the larger firms.

While the value of fabric is a major proportion of final costs these costs are comparable for manufacturers worldwide. It is in the area of reducing labour costs in the assembly stage. accounting for about 80 per cent of all labour costs, where savings are required, if any dramatic shifts in comparative advantage in favour of the developed countries are to occur. The technical changes which have occurred in the sewing room. while significant for certain sub-processes, are nowhere near the same magnitude as seen in the earlier phases of the garment manufacturing process.

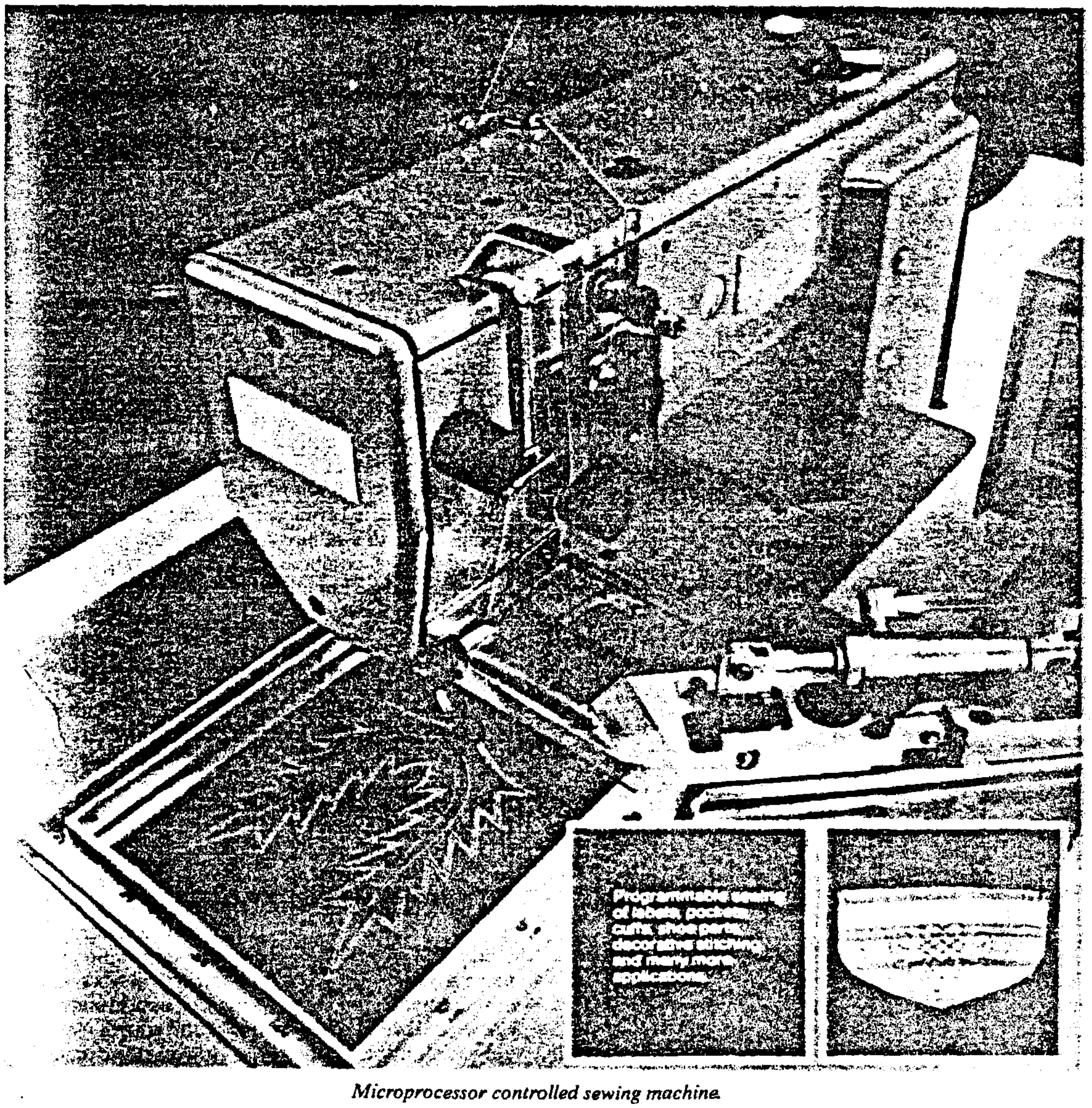
The range of different sewing tasks that need to be carried out at the assembly stage is very wide and can involve complicated stitches requiring a very great deal of skill. In most cases. highly irregular shapes of different lengths are involved—all of which change as fashions vary. To compound the problem. many factories are required to make only a few units of the same size and shape at any one time. and often have to mix batches and orders.

The technical problems for mechanising and automating such a process are as obvious as they are formidable. The use of microelectronics has. however. allowed for two types of semi-automatic sewing which although they do not completely replace the operator. do increase productivity while at the same time reducing skill levels and training time. The first incorporates a dedicated microprocessor in specialised pieces of equipment for small parts assembly ie collars. cuffs. belt loops and pocket setting. These machines produced by a wide range of firms including Union Special. Pfaff. Durkoff. Neechi, Juki and Reece. cost in the range of $15.000-40.000. and allow a *high volume* producer to increase productivity by anywhere from 50-300 per cent by increasing the speed and combining a number of operations. eg in the case of collar attachment. these machines reduce the number of operations from 11 to 3.

Long runs. infrequent style changes and more than one operating shift are necessary for these reliable. extremely efficient. but relatively inflexible machines. The second category of sewing innovations are distinguished by the use of programmable memory chips. At $5.000-$8.000 these machines can be computer programmed and controlled to perform a large variety of stitches in either decorative or functional sewing tasks. When combined with photo-electric edge-sensing equipment, these machines will monitor the edge of the material to be sewn and disengage the needle when required. One leading manufacturer quotes an independent evaluation of this system which claims that productivity is improved between 25-66 per cent for a variety of operations such as top stitching collars, setting shirt pockets and attaching collars.

With approximately 80 per cent of the average garment manufacturer's labour and capital costs associated with the assembly phase, the subsequent concentration of innovative activity in that area is justified. Given the current technical difficulties and potential savings in the sewing room it is also hardly surprising that the finishing stage has been relatively neglected. This is reinforced by the pervasive attitude among management that the function of pressing is primarily in making the product 'presentable' or 'saleable' rather than an essential component of value added.

This attitude is likely to change as modernisation in the industry fosters more sophisticated methods of cost justification. Two capital equipment manufacturers



Beta Engineering and Development Ltd.

Microprocessor controlled sewing machine.

recognising that the 10 per cent of capital expenditure estimated for this stage also signifies a high degree of labour intensity, have now incorporated microelectronics into their pressing equipment.

Magpi/Sussman and Certus have introduced first generation pressing equipment for jeans, slacks and suits which incorporates microelectronics. In flat pressing jeans using this equipment, six pairs of jeans can be pressed per minute, or over 2,000 pairs per day, while suits can be pressed at the rate of 400 per day. While Certus' equipment goes some way towards providing a more continuous pressing of separate parts of a garment (ie sleeves, armholes, shoulders etc) and Sussman's allows the operator to choose from 12 pressing variables (ie steam pressure, temperature, etc) neither machine, whose cost ranges from $30,000-$200,000, have operated under production conditions long enough for an accurate assessment of their operating performance. What is currently evident is that for a limited number of products (jackets, jeans) these machines can be used to reduce both training times and the skill of the operator, previously required to ensure quality.

Implications for the Third World

While the fully automated garment production system is not at present a reality, the trends in technical change and the expectations in the industry are unmistakably oriented in the direction of increasingly comprehensive systems development—although it is likely that change will continue to be gradual rather than rapid—extending into medium to long term as opposed to the overnight changes predicted by some observers.

The structural and institutional problems discussed earlier which impeded the historical rate of technical change, will also slow the rate at which MRIs are introduced by manufacturers in the developed countries. The high capital costs of the systems and the advanced management and maintenance skills required to operate them efficiently mean that the large manufacturers will be best placed to use the equipment. Interestingly, these large firms are also those most heavily involved in offshore manufacturing and producing under USA 807.00 import type clauses. Hence, they will be able to gauge very accurately the relative costs of producing garments offshore using cheap foreign labour as opposed to home based production using advanced technology.

Although it has not happened yet, to any great extent, there is a feeling among the large producers that a large share of offshore production will be brought back. In those cases where these firms have located manufacturing facilities in developing countries with large domestic markets, we would expect that the equipment would be introduced if competitive conditions required such a move.

Both of these scenarios have significant implications for developing countries.

Locally owned Third World firms produce and export an extremely wide range of garments that vary enormously in terms of quality and cost. Traditionally, they have concentrated their efforts on standardised products of low to medium quality which have a wide demand in western countries—blue jeans, skirts, blouses, shirts, jackets, etc. More recently, however, they have been successfully moving 'up market' with their exports and are increasingly competing with developed country producers in high fashion sub-sectors such as suits and dresses, where profit rates are higher and there are fewer tariff barriers. Their comparative advantage, however, remains based on cheap labour rather than on improved technological capability.

Although Third World firms do have access to quite a large range of techniques on the international machinery market, they tend to rely extensively on conventional multipurpose machines and cheap labour to perform manually the tasks which will become increasingly automated in the developed economies. This combination gives them the capacity to mass produce standardised products at low prices and enables them to respond quickly to ever changing fashion requirements and competitive conditions. These characteristics will allow Third World producers to resist the effects of microelectronic based technical change. But this ability to resist must gradually be eroded by the combined effects of rising domestic wages, higher and broader tariff barriers and innovations increasingly directed at precisely the activities where they now enjoy comparative advantage. As we have already mentioned, the crucial variables in this process will be the rate at which these applications will be developed and their speed of diffusion within the advanced industrial countries. Across sub-sectors, this will be an irregular and discontinuous but nevertheless inexorable process that is already signposted by current developments.

Such a process will create problems for some Third World producers, particularly those countries which are really only beginning to develop their apparel industries. The renewed strength of western manufacturers and the already entrenched position of the more advanced developing countries will work against any dramatic expansion of market opportunities for the least developed countries of the sort that fuelled industrialisation for the NICs. However, the die is not yet cast and some time will elapse before these changes really begin to take effect. In the intervening period, these poorer developing countries will need to make a much clearer assessment of their strategies to develop the garment sector in the light of the effects of micro-electronics on the structure of the industry in western economies.

Electronics and the Technology Gap—the Case of Numerically Controlled Machine Tools

Staffan Jacobsson

Introduction*

There are two facts which must be confronted by a social scientist with an interest in capital goods and the developing countries. The first is the emphasis that some developing countries put on the growth of an indigenous capital goods sector. India, Brazil, and the Republic of South Korea are particularly notable but Argentina and Mexico should not be overlooked. The second fact is the trend towards an automated production system in the engineering sector in the developed countries. With the development of microelectronics, the concept of the fully automated factory in branches characterised by small batch production has finally turned out to be feasible. Whilst there are only a handful of partially automated factories in operation today, the diffusion of *individual components* that will make up such a system is well under way. This applies not only to numerically controlled machine tools but also to robots and automated material handling systems, as well as computer aided design systems. Whilst the integration of these elements has not on the whole been carried out yet, the diffusion of each element on its own may have significant effects on productivity and therefore on comparative advantage in the engineering sector.

This article, which is based upon research in Sweden and Argentina, addresses one particular element in automated production—numerically controlled machine tools (NCMTs). First, I will attempt to analyse the direction of technical change in terms of any factor saving bias. In other words, has the electronification of NCMTs produced a technology which is more appropriate to the developed countries or to the developing countries? Second, I will try to analyse the impact which this technological development may have on the comparative advantage of the newly industrialising countries (NICs).

*This paper is part of a research project dealing with the production of numerically controlled machine tools in the developing countries. The project is financed by the Swedish Agency for Research Cooperation with the Developing Countries whose assistance is gratefully acknowledged.

The technology

Traditionally in batch production, the need for flexibility has meant that standard, hand operated and multipurpose machine tools have been used. As a consequence exceptionally good quality has been difficult to achieve, the level of machine utilisation has been very low due to long change-over times from one product to another, and very skilled people have been needed to set and operate the machine tools. At the beginning of the 1950s, the first NCMT was developed in which the information needed to produce a particular component was put on a medium (eg a tape) and fed into a numerical control unit. By simply changing the tape, the NCMT could quickly be switched from the production of one type of product to another. A large gain in flexibility has been gained. But the cost and unreliability of the electronic components hindered a wide diffusion of this technology until minicomputers were introduced in 1970. A still more significant change in the technology, which indeed may be looked upon as a great qualitative change as opposed to a change in degree, was the use of microcomputers for the numerical control unit, which were introduced in 1975. The use of microelectronics meant a drastic reduction in price, an increase in reliability, a simplification in programming and the spread of electronics to a range of functions previously not automated, such as tool changing and diagnostics. The technology has now, five years after the introduction of microelectronics, reached maturity and is consequently diffusing rapidly.

The diffusion of NCMTs

The rapidity of diffusion of NCMTs in the developed countries can be seen from the following trends: in Sweden the share of NCMTs in all machine tools (in value terms) rose from 12.4 per cent in 1974 to 35–40 per cent in 1979. Numerical control systems are however mainly applied to metal cutting machine tools—as opposed to metal forming ones—and here the share of NCMTs as a proportion of metal cutting machine tools rose from 22.8 per cent in 1974 to 54.1 per cent in 1979. In Japan the share of NCMTs in all metal cutting machine tools rose from 17.4 per cent in 1975 to 35.7

per cent in 1979. In the case of lathes, one of the most important metal cutting machine tools, the share of numerically controlled lathes was still higher, accounting for 51 per cent in Japan and for around 70 per cent in Sweden and France in 1979. The rapid growth in importance of NC lathes can be appreciated when we note these figures against earlier time periods. In the case of NC lathes their share was only 26.4 per cent in France in 1976, 23.4 per cent in Japan in 1975 and 34.4 per cent in Sweden in 1974.

The direction of technical change

The rapidity of this diffusion is explained by the following factors:

a) the most important source of productivity increase in savings in labour. For example, a NC lathe substitutes for between two and four conventional lathes. Thus two to four lathe operators are substituted for by one NC lathe operator. In some cases this NC lathe operator can attend two machines, as his function is mainly a supervisory one. Furthermore, as NC lathes contain a computer, various computer guided feeding mechanisms can be attached to the NC machine tools, further reducing the amount of labour time. Moreover, as we shall see, the rate of utilisation of NC machines is higher than for conventional machines, thereby further enhancing the productivity of labour;

b) NCMTs may also save capital. The flexible character of NCMTs means that the capital embodied in stocks and work in progress may be substantially reduced. This is very important as, for example, in the Swedish mechanical engineering sector in 1977, 30-35 bn kronas were tied up in goods (stocks and work in progress) and only 15-20 bn kronas in machines and buildings. NCMTs also aid in this capital rationalisation process in that they save space. This is an often overlooked source of increase in the productivity of capital. (In fact in 1977, the value of investment in buildings in the Swedish engineeering sector was 84 per cent of the investment in machinery.) In general, the capital saving nature of these aspects offsets the effect of the higher price of the NCMT in relation to standard machine tools, leading to a lower capital cost per unit of output;

c) automatic positioning and control allows for greater precision and uniformity of quality;

d) the existence of flexible manufacturing systems which can cut lead time is playing an increasingly important role in firms' strategies in the face of tough competition.

The skill implications of NCMTs

There has been a significant reduction in the skills needed to operate the machine tool as well as a reduction in the *number* of people embodying the skills. An NMCT operator clearly needs some skills, but the maximum time at work and at in-house training courses required for an unskilled person, who has had a technically orientated secondary education, was said by one firm to be 12 months. Other firms suggested a maximum of six months. By contrast, for a qualified operator of a conventional lathe, five years of experience is often mentioned as being necessary merely to acquire proficiency. One firm visited, which had started up with NC lathes, only needed to employ 22 semi-skilled NC operators instead of 44 skilled operators. In another case, 21 NC operators substituted for 63 qualified operators. Hence, for the operation of the machine tools the 'mass' of skills needed has been reduced in a very significant manner. However, NCMTs require a set of other skills which are not important in the case of standard machine tools.

First, in addition to the NC operators, instructors and programmers are needed. Hence, there is a further division of labour. Roughly six to eight NCMTs are served by an instructor and a programmer. These people are often former skilled workers who have joined the ranks of the white collar workers, or people with some technical training. for example technically orientated secondary education.

Second, repair and maintenance has become more complex. This does not apply so much to the mechanical parts, which are in fact simpler in a NCMT since it has less moving parts, but to the electronic parts and the interface. Given that for most users. apart from the larger firms, the electronic part is of a black box character, there is a tendency for the supplier to take over the repair and maintenance work. Usually, there is one engineer employed for 15 installed NCMTs. At the level of the machine tool, the introduction of NC units has increased the skill requirements. However, as the number of machine tools is decreasing due to increases in productivity, the *amount* of repair and maintenance skills needed to produce a given number of engineering products has not necessarily increased.

All in all, the very dramatic decrease in the number of skills needed at the operational phase is only marginally offset by other skills required in the supervision, programming and repair and maintenance tasks.

Effects on global comparative advantage

In view of the substantial benefits provided by NCMTs to investors, it is obviously important to determine the impact on users in the developing countries and on global comparative advantage. Contrary to initial expectations there are reasons to believe that the diffusion of NCMTs has the potential to enhance their comparative advantage, especially that of the newly industrialising countries (NICs). We now consider these.

Let us sum up the advantage of NCMTs: firstly. firm interviews clearly show that the NCMT is a *capital saving* technology. The degree of capital saving in *relation* to conventional technology depends. however. to some extent on the institutional setting. In many developed countries it is difficult. if not impossible. to find skilled workers who are willing to work shifts. This institutional restriction to the full utilisation of all fixed capital. including buildings. probably does not apply to the same extent in the NICs. The skill saving character of NCMTs means that the firms based in a developed country can to some extent overcome this restriction to fuller capital utilisation. and NCMT operators in developed countries were found to be more likely to work two shifts than those firms using conventional technology. As this is probably not an issue in the NICs. we can conclude that NCMTs are slightly more capital saving in relation to conventional machinery in a developed country than in a NIC.

Secondly. NCMTs save on labour in a very dramatic manner. Proportionately more labour is saved than capital. At first sight this might lead us to conclude that the NCMT is a technology which is more appropriate to the developed countries than to the NICs. However. the labour saved is predominantly *skilled* labour and the labour which remains is mainly unskilled or semi-skilled labour. The total mass of skills required to produce a given set of engineering products has thus been significantly reduced. Thus. proportionately speaking. reduction in skill requirements is of far greater magnitude than the capital or labour saving nature of the NCMTs. This means that the NCMT represents a technical change. the appropriateness of which is a function of the degree of scarcity of skilled labour compared to capital and/or to unskilled labour.

This conclusion is important since it is clear that skilled workers have traditionally been a major source of the developed countries' comparative advantage in the engineering sector. In fact. one study concluded that in the case of Sweden. the comparative advantage moved between 1960 and 1970 to branches with a more intensive use of skilled workers [Ohlsson 1976].[1] With NCMTs. production of some engineering goods need no longer be placed in economies with an abundance of skilled machine tool operators. As in all other automated production technologies. NCMTs are mobile. and in the future such factors as wage costs and 'workers' discipline' can be expected to be added to other determinants (such as labour skills) of the international location of production.

[1]Elaboration of data supplied by the Swedish Union of Metalworkers.

To sum up. there are strong reasons for suggesting that NCMTs represent a technical change which is to the benefit of economies with factor endowments of a kind that are usually associated with the NICs. Hence. the *direction* of technical change favours these economies. To what extent this has actually shifted or reversed the comparative advantage of these NIC economies is. however, more difficult to substantiate. This depends on the exact level of skills in the relevant countries. To answer that question we would need very detailed knowledge of the relative scarcity of the different factors of production in all the relevant countries. However. as a minimum statement. we can safely say that the comparative advantage of the developed countries in metal-cutting has been eroded by NCMTs.

Before drawing too strong a conclusion from this analysis, there are three important considerations to bear in mind:

a) NCMTs only affect production. even if design is being computerised via Computer Aided Design systems [Kaplinsky 1982]. These changes in design technology which appear to be diffusing more rapidly to developed economies. may provide significantly greater benefits. particularly in sectors where product-competitiveness outweighs price-competitiveness.

b) Metal-cutting is only one out of many sub-processes in the engineering industry. Others of importance are metal-forming. casting. heat treatment. joining, assembly, material handling and quality control. In the case of Sweden in 1980. the five largest groups of workers. in terms of hours worked, were: assembly (21 per cent). machine tool operators (14.6 per cent). material handling (7.6 per cent), welding (6.6 per cent) and quality controls (5.9 per cent). Hence. machine tool operators constitute only a small proportion of the total workforce. Furthermore. metal-cutting varied in importance between various products, and the above reasoning applies only to very specific products where metal-cutting accounts for a large proportion of production costs. An example of such a product would be pumps, while electrical motors would be less affected.

c) The present industrial structure of the NICs is such that those branches in which it is profitable to use NCMTs intensively tend to be relatively under-developed. Hence. the diffusion of a large number of NCMTs to these economies will take as long as it takes their industrial structure to alter. Of course. the change in comparative advantage through NCMTs may speed up this restructuring process. but there are many other factors at work determining cost differentials.

The present diffusion of NCMTs to some NICs

What, then, is the evidence concerning the utilisation of NCMTs in the NICs? There are several ways of measuring the intensity of use of NCMTs. Firstly, one may simply note the number of installed units in the various economies. Thus whereas the US had 54,000 (1978), West Germany 25,000 (1980), the UK 10,000 (1976), and Sweden 4,000 (1980), Argentina only had a total of 325 (1980), Brazil 650 (1979), India 130 (1979) and the Republic of South Korea 1,000 (1980). All in all then, the total stock of NCMTs in the NICs may be around 2,500. This is clearly an insignificant number in relation to the number installed in the developed countries. Furthermore, against the present large-scale penetration of NCMTs in the OECD countries, the prospects for the NICs may seem even bleaker. For example, Japan alone installed 8,398 NCMTs in 1979 and the UK doubled its installations of NC lathes between 1978 and 1980.

However, the mere comparison of numbers is not the correct way of answering the question. The number of installed NCMTs must be related to the size of the relevant metal-working sector. Not all branches in the engineering sector use NCMTs. It is only in branches which are characterised by batch production that one may advantageously utilise NCMTs. A study of the diffusion pattern in Sweden revealed that 83 per cent of installed units may be found in nine branches (at four and five digit ISIC level). Hence, the number of installed NCMTs would need to be related to the size of these nine branches in order to get a reasonable idea of the degree of penetration of NCMTs in various economies.

Table 1 relates the number of installed NCMTs to the sales value in these branches in Sweden, Argentina, Brazil and the Republic of South Korea. India has been omitted as it has only 130 installed units. We find that the Republic of South Korea has an intensity in use of NCMTs which is higher than that of Sweden's! Argentina is close to the Swedish figures for 1976 for the case of NC lathes, but has only slightly more than half of Sweden's 1976 intensity for all NCMTs. Brazil (as well as India) lags very far behind. We should note that the data exaggerate Brazil's intensity in use of NCMTs as the sales value is from 1974, whilst for the rest of the countries 1977 sales values have been used.

The difference in the intensity of use of NCMTs in the NICs would appear to reflect the general economic policies of the countries. The exceptionally high Korean figures reflect to some extent Korea's weakness in the relevant branches, but also reflect its heavy emphasis on building up a capital goods sector. Furthermore, Korea has a very short history of skill generation in these branches and should benefit more from the skill saving character of NCMTs than, say, Argentina, which has a long history of capital goods production as well as a long history of immigration of skilled metal-workers. Argentina's lower figure reflects, however, its deep economic crisis after 1977 when the diffusion of NCMTs really started to take off in most other countries. Brazil's exceptionally low figure most probably reflects its policy of import controls, which impedes the diffusion of capital embodying new technology.

In conclusion, of the countries considered, Brazil and India are falling behind in the use of NCMTs. These countries will therefore probably be left behind in productivity growth as well. Korea, on the other hand, is investing heavily in NCMTs and should benefit proportionately more than the advanced countries by this technical change. Argentina falls somewhere in between.

Conclusions

Looked at in isolation, the NCMT is not a technology which will necessarily lead to an increased technological gap between the developed countries and the NICs. On the contrary, given the right economic policies in the NICs, eg allowing access to NCMTs at world market prices, it is a technology which is at least as suitable to the NICs as to the developed countries. The NCMT has therefore to some extent reduced the comparative advantage of the developed countries in metal-cutting. It is furthermore possible, but not necessary, that it has reversed comparative advantage in favour of the NICs. Hence, the international diffusion of NCMTs may well be associated with an increasing share of these countries in world production and trade in engineering products. In particular, this applies to the Republic of South Korea which has invested heavily in NCMTs as part of its plans to build up a capital goods sector.

There are a few points, though, to be borne in mind:

a) the change in comparative advantage applies only to the production stage and only to products where metal-cutting is of importance;

b) the industrial structure of the NICs needs to be altered in order for them to be able to utilise NCMTs. This applies especially to the Republic of South Korea, but also to Brazil.

Finally, we need to say a few words about the long term trends in engineering technology, as NCMTs represent only one discrete element in the automation process. We noted earlier that the NICs could gain a competitive edge through both lower labour costs and higher utilisation of fixed capital. Automation will affect both these sources of comparative advantage in the future.

table 1

Intensity of use of NCMTs and NC lathes in four countries

	sales value (bn dollars)[1]	*number NCMTs*	*number NC lathes*	*2/1*	*3/1*
Argentina	2.83 (1977/78)[2]	325 (1980)	215 (1980)	114	76
Brazil	8.4 (1974)	649 (1979)	196 (1979)	77	23
Korea	1.55 (1977)	1,000 (1980)	493 (1980)	645	318
Sweden	8.68 (1977)	4,000 (1979)	1,665 (1979)[2]	460	231[2]

[1] Sales value refers to 9 branches (ISIC 3811, 3821, 3822, 3823, 3824, 3829, 3831, 38322, 38432). For Argentina ISIC 38322 is excluded due to non-availability of data.

[2] Estimated.

Sources: Argentina: sales value is estimated from data supplied by INDEC. The number of NCMTs is estimated from interviews.
Brazil: sales value is taken from *Censo Industrial 1974.* The number of NCMTs from Stemmer 1981.
Korea: sales value is taken from *Report on mining and manufacturing survey 1977.* The number of NCMTs is based on *The Korean Development Bank 1980,* and various statistical yearbooks on foreign trade.
Sweden: sales value is taken from Sind 1979:11. The number of NCMTs and on SOU: 1981:11.

Concerning labour costs, let us go back to the distribution of labour among the different sub processes in the Swedish engineering industry to illustrate my point. In metal-cutting, the proportion of skilled workers is still very high at 51.6 per cent, whilst in, say, material handling it is only 7.6 per cent, and in assembly only 22.5 per cent. This suggests that NCMTs may substitute for skilled workers in metal-cutting so that a NIC could use its relatively low cost semi- or unskilled labour not only for metal-cutting but also for assembly and material handling etc in order to gain a competitive advantage. Underlying this suggestion is a theory of uneven development of automation in the engineering sector. Without attempting to provide full proof, it appears that automation has developed most in the metal-cutting phase, where it substitutes for skilled labour. It has been less developed in assembly and material handling, where it substitutes, to a larger extent, for semi-skilled labour. In the longer run, automation is expected to proceed to these sub processes too. For example, Hitachi hopes, to develop a 'skilled robot' for the assembly of electrical products within five years [*Japan Economic Journal* 1981]. When these techniques are developed, they will withdraw the basis for cheap labour competition from the NICs. Hence, technical change may in the medium and long term alter the basis for a change in comparative advantage.

With automation also comes an increased possibility to put fixed capital to better use. Already there are techniques developed which feed the NCMTs automatically with parts. The only human intervention needed is to provide the robot or feeding mechanism with a pile of parts. This means that a NCMT can already work for as long as six hours without human intervention.

In the long run, the process of integrating the individual components into the automated factory will pick up speed. Partially automated factories exist, even now. The integration of computer aided design with NCMTs and robots as well as automatic warehouses implies a shift in technology which is of a fundamental nature. Whilst the introduction of a discrete element, say a NCMT or a spray robot, is relatively simple, a system change requires a user competence which is qualitatively different. It is unlikely that NIC-based firms in general will easily follow such a system change.[2] However, we are not yet at the stage of automated production.

[2] This is of course highly speculative. There are a number of technically progressive firms also in these countries. For example, the Argentinian heavy capital goods firm Pescarmona has not only a very large number of NCMTs but is also installing Computer Aided Design in an effort to break into the world oligopolistic market of heavy electrical equipment.

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Is There a Skill Constraint in the Diffusion of Microelectronics?

Raphael Kaplinsky

Introduction

In this contribution we aim to focus on the skill implications of the introduction of a new microelectronics based technology which involves a radically different work practice from that involved in the established processes. The technology referred to is computer aided design (CAD) and relates to the dual activities of design and draughting. Before we discuss these skill implications, we first describe the technology, summarise the results of a major study involving field research in Europe and North America [Kaplinsky 1982] and assess its impact (and by implication, that of microelectronics based technologies in general) on developing country comparative advantage.

Computer aided design technology

CAD is a particularly good example of a software intensive industry. Building on a fairly standard set of microelectronic hardware (predominantly minicomputers) and peripheral components (television screens, computer memory, drawing devices and electronic drawing boards) systems are available to undertake a wide range of tasks to assist designers and draughtspersons in their work. This assistance is of two major sorts. The first involves *basic graphic software* which speeds up the process of drawing; the second involves a wide variety of *applications programs* to meet particular design needs in all sectors of engineering (electrical, civil, mechanical, chemical), cartography, business analysis and animation.

The price of these systems starts from around $30,000 for a single terminal system which is suitable only for drawing, to around $1.5 mn for a 30 terminal system which provides both a wide variety of analytical applications programs and a capability to undertake numerous, unrelated batch processing tasks such as payrolls and customer billing. Of these prices, around 30 per cent is hardware; the rest comprise of overheads and a considerable input of software. Some of the turnkey vendors have accumulated well in excess of 1,000 person years of software with over seven million lines of software code in the suite of basic graphics and applications software which they offer.

The origins of this industry lie in the aerospace and defence sectors of the late 1950s and 1960s. By the early 1970s CAD began to be used in the electronic sector, diffusing to mechanical engineering and cartography over the past five years. The industry expects the civil engineering and architectural sectors to be the major growth point in the second half of the 1980s. The achieved growth of this sector has been quite remarkable. Having reached around $80 mn in 1976, the sector 'took off' with the value of output reaching around $1 bn in 1980. Projections of sales value for 1984 are between $5 bn and $8 bn. By comparison, the projection for global sales of robots is only $2 bn by 1990, and only $4 bn for colour TVs in the USA in 1984. As another indicator of the phenomenal growth of the CAD sector, if the industry had grown at the same rate as IBM between 1976 and 1980, its sales would have only been around $120 mn in 1980, and if it had followed the same growth path as DEC (the most successful of the minicomputer firms, the 'success story' of the 1970s), its size in 1980 would only have been around $250 mn.

This very remarkable growth path follows in part from the benefits arising to users (see below). But it also follows from the fact that CAD has a key role to play in the development of the automated factory, since it is in the design phase that the data base for production and information control is defined. Hitherto there has not been great progress in the development of automated factories, but with the growing maturity of CAD and flexible manufacturing systems, most of the components of these automated systems now exist. The cutting edge of technological progress lies now within the sphere of organisation since the synergies between various parts of the system, and the implications for altered staffing and skills patterns, requires systems' reorganisation. The bottlenecks in this phase of automation are probably as much social as technical.

The benefits to use

Assessing the benefits of using the technology is problematical since there are such a wide variety of uses, since design is essentially a craft-based activity (and is hence susceptible to variation, as are all labour-intensive tasks) and since the technology has only recently 'matured'. Nevertheless it is possible to make a preliminary attempt at classifying the types (and

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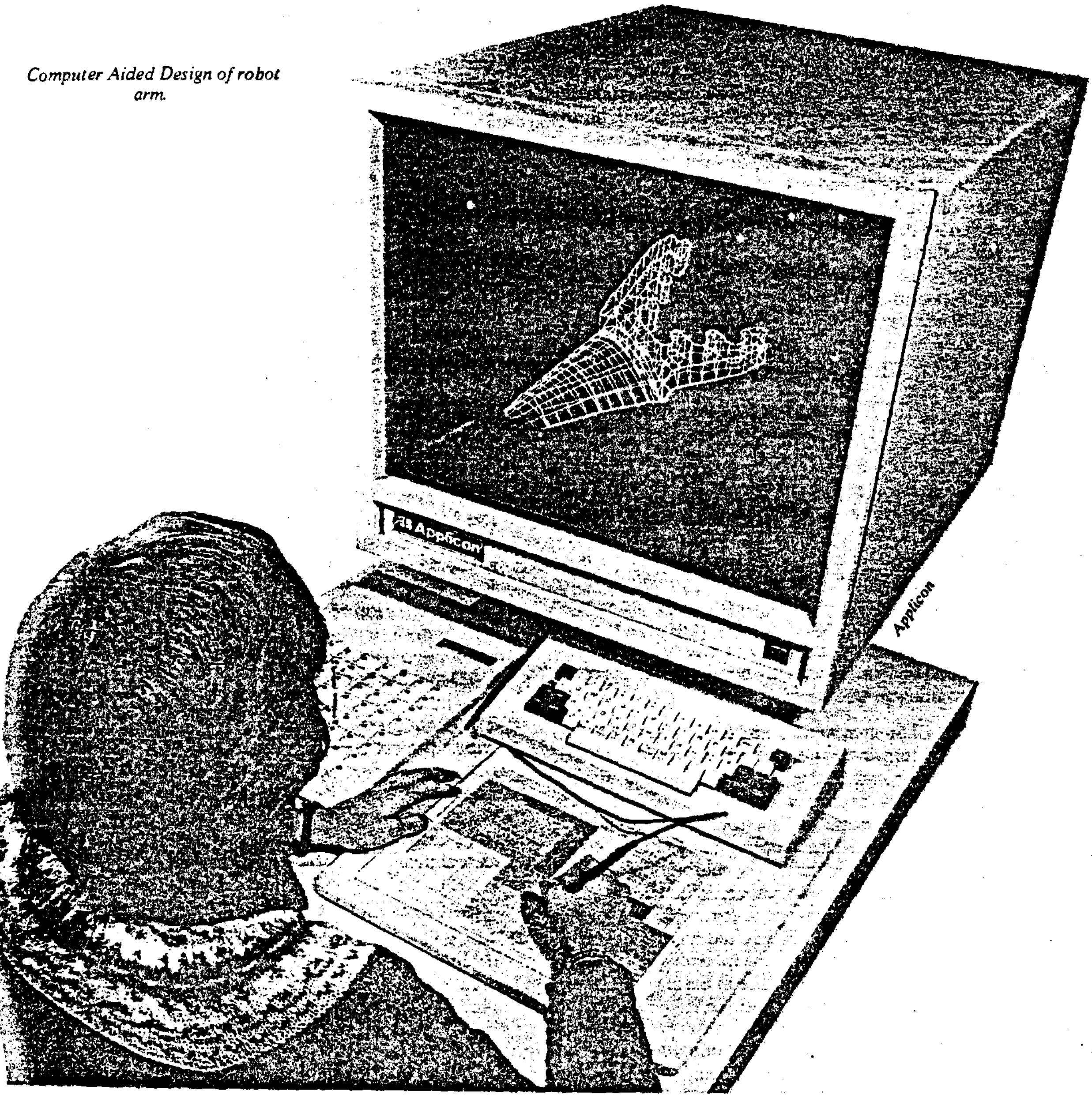
even the extent) of benefits accruing to user-firms (but not necessarily to the workers involved!). Four major types of benefits emerge, namely in:

Draughting
Average productivity gains were found to be in the region of 3:1. Given the cost of the equipment, a three year pay-back period and this level of productivity gains, we estimate that it pays firms to use CAD on a two shift basis when the gross payroll cost (ie including overheads) of draughtspersons/designers exceeded $5,500. This is a level which is exceeded in many developing countries.

Design
Here CAD offers a number of different benefits depending upon the sector. In some sectors (eg electronics, aerospace) it is essential—the product

Computer Aided Design of robot arm.



could not be produced without it. In other sectors CAD allows for greater optimisation of product design (eg reducing wind resistance of motor cars which improves fuel efficiency). In almost all firms visited CAD played a crucial role in reducing the lead-time required to get the product on to the market.

Downstream benefits

The use of CAD offers a wide range of benefits (which at this early stage are still largely potential, rather than realised) in downstream activities such as setting machine controls automatically, testing products and helping in the control of inventories.

Control

From management's point of view CAD provides a very important benefit in enhancing control over the design and draughting staff and, by allowing for selective access to the design details, in reducing the flow of technical secrets to competitors.

Impact of CAD on comparative advantage

Given that design and draughting are only subsets (albeit key ones) of the process of producing and marketing an attractive product, it is difficult to argue that it alone will affect the international division of labour. Moreover given developments in communications technologies (notably via satellites) it is entirely feasible to set up design facilites in one continent and production plants in another. We are consequently forced to see CAD as an example of one of many emerging microelectronics based technologies and to argue, ex hypothesis, that the conclusions derived from this technology are relevant to those derived from other ones.

To the extent that it is possible to assess the likely path of diffusion of CAD technology we are drawn to the following firm conclusion. The technology is likely to diffuse most rapidly to precisely those sectors in which developing country manufactured exports grew so rapidly in the 1970s [Kaplinsky 1982]. The traditional-manufactures sectors (ie shoes, garments, leather products and semi-manufactured textiles) are likely to be *relatively* less affected by CAD technology—a view which mirrors the conclusions of Hoffman and Rush in their article in this *Bulletin*. What this means, therefore, is that the emerging comparative advantage of the NICs in higher technology sectors is likely to be undercut in the 1980s, if other microelectronics-based technologies offer similar benefits to users and diffuse in a similar pattern as CAD.

Skill implications of using CAD technology

In a growing number of sectors, therefore, CAD either already is, or is rapidly becoming, a mandatory technology if firms are to compete effectively in increasingly competitive markets. Our attention is thus naturally drawn towards the skills required to make efficient use of this radical new technology. Earlier discussion pointed out that, as with many new electronic technologies, the gains derived from using CAD are felt not only within the narrow confines of draughting but span the whole system of factory organisation. Consequently in discussing the skills involved in its efficient utilisation, we must consider both operator-skills and management skills as well as the learning curves which are involved. At the same time a software intensive technology such as CAD requires extensive back-up and service-skills from the suppliers if it is to be run efficiently.

Skills

i) *Operator skills*—There was a fairly strong consensus amongst all users visited that, at the worst, the skills required to operate CAD systems are the same as those involved in manual systems, and in more favourable circumstances, the required skills are lower than those with which traditional draughtspeople are equipped. As far as *draughting* is concerned, CAD (like other forms of mechanisation) deskills the job and reduces it to machine operation. By contrast in the case of *analysis and design*, by removing the unskilled element, CAD distils the skill component for concentrated attention by the designer. We see here a difference in the position of draughtspeople and designers—the skills of the draughtsperson are, in effect, boring constraints for the designer.

Both operators and management conclude that CAD reduces the skill component in draughting because it removes the craft element (requiring extensive practice) associated with individually-tailored layouts and individually developed lettering. This is not to say that CAD has no specific skill requirements, but that the type and levels of skill are altered. Most management reported that typing skills were an advantage, given that all CAD systems have an alphanumeric keyboard for entering at least some of the data. But, as far as management is concerned, attitude and flexibility are more important attributes; some management felt (with no apparent justification) that these were a function of youth; one system manager claimed that 'females were less flexible and dexterous' despite the existence of many female CAD operators, particularly in the USA. Finally one firm, which has a particularly rapid screen response time, argues that manual dexterity is an important attribute—thus while the average IBM CAD operator works at around 30 interrupts per minute, the best UK operator has been timed at 70 per minute and best US performance is 100 interrupts per minute. Thus it was the view of most management that although a good draughtsperson makes a good CAD operator, the CAD system was sometimes able to make a good operator out of a bad draughtsperson (eg someone who was sloppy at lettering).

ii) *Management skills*—The skills required by managers (as opposed to operators) of the CAD system are of a more substantive nature, for three reasons. Firstly, as we saw in the previous section, many of the benefits of CAD are felt downstream. The current state-of-the-art of CAD technology is generally one in which the basic draughting-gains have been mastered and the cutting-edge of progress lies in capturing these downstream benefits. While this latter task is partly a function of improved software, it also requires a changed attitude by management which is still feeling its way towards new forms of systems organisation. Secondly, even within the draughting/design stage, management has an important role to play in improving productivity. Whilst operators are able to build-up their skills until they can use the CAD system rapidly, for the real benefits to be obtained the draughting office has to be well-organised. And finally, management argues that it has an important function to perform in evening out the performance of individual operators into a curve of continuous and harmonised growth for the CAD system as a whole.

Given these taxing demands upon management, it is not clear that any particular skills (different, that is, to pre-CAD skills) are required. However a *vision* of systems gains and the *power* to implement organisational changes are of critical importance. And to the extent that these attributes are necessary it is not evident whether these can be formally learnt or whether they are acquired through direct experience.

Back-up services

CAD systems are new, different and software-intensive. Users consequently require a great deal of back-up assistance from suppliers until their systems function efficiently, particularly when the innovating firm is not experienced in using analogous types of equipment (such as automatic testing equipment)—indeed, this ability to supply assistance to users is a major competitive factor in the supplying industry. For example, the major supplier aims to have in Europe one software-support engineer for every eight systems in use and one hardware maintenance engineer for every four systems. In addition it has a further 24 software staff in the UK alone who service the home market and parts of the European market.

The services offered by these suppliers relate predominantly to software. Most suppliers reported that over 50 per cent of software problems turn out, on inspection, to reflect the 'ignorance' of users. But in addition to the ongoing support services which suppliers offer, the growth of users' systems efficiency is enhanced by specialised courses which all suppliers provide (usually at a price) as well as by regular users' groups in which users can exchange experience and bring collective pressure to bear on suppliers. The dominant conclusion which emerges from all this is that 'closeness' to CAD suppliers and users is important for efficient use, requiring an ongoing 'handholding' relationship.

The learning curve

Obviously the learning curve of both operators and management depends largely upon the use to which the CAD system is put. For example a system used for pure draughting is generally easier to assimilate than one used for design or the capturing of downstream benefits. On the other hand, such limited uses (characteristic of unimaginatively managed systems) may well reflect the inability of management to learn to use CAD effectively. As a general observation, it appears as if there is a trade-off between the rate of learning (of both operators and managers) and the ultimate success with which the system is used. The too-rapid definition of procedures which assist in obtaining early gains in productivity, has the effect of boxing-in the future potential of the system.

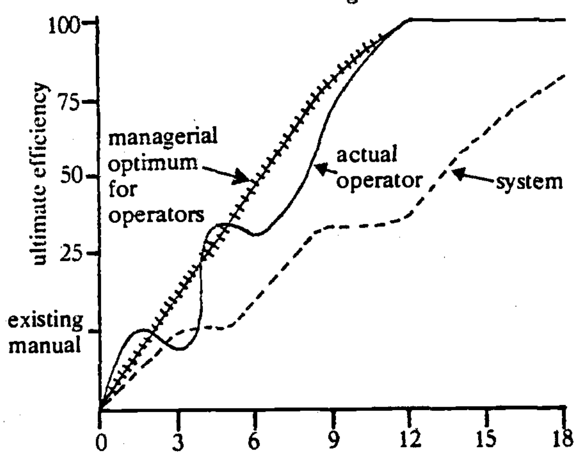
The slope of the learning curves can be steepened in a number of different ways. One is to send both operators and managers away on courses, or to institute formal in-house training programmes. In fact most CAD suppliers included a series of basic courses in their sales price and offered a range of specialised courses for particular applications programs. A second strategy, generally pursued by enterprises for whom rapid progress is vital, is to poach expertise from existing CAD users. This presents gains to both the purchasing firm and the individuals involved. Thirdly, management often gained important experience from conversations with counterparts at the Users' Groups organised by most turnkey suppliers.

On the basis of discussions with both management and operators in firms using CAD, it is possible to simulate a series of learning curves, as is done in Figure 1 below. Insofar as operators are concerned, learning occurs in a series of steps. At around three months, or earlier, most operators are up to the level of productivity of manual systems. There is then a short period of retrenchment while the operator assimilates the newly-learnt basic operating skills which are threreafter continually improved via the assistance of menus, until around six months. Then the operator begins to take advantage of the sub-designs stored in the CAD system and makes more effective use of analytical programs. Most users reported that by the end of the first year, most operators were about as efficient with the system as they could ever get—further benefits depended upon the back-up provided by systems organisation. There was, however, some difference in the views of users about whether the period of individual retrenchment was associated with a flattening of the curve or a temporary decline in productivity—since we encountered sufficient of these latter views we believe that a temporary fall-off in productivity is a common experience.

One of the functions of management is to iron-out these periods of individual retrenchment and thereby to increase the general productivity of the system by moving the industrial operators to a more desirable learning curve. This can be done by providing special assistance to operators experiencing difficulties, but it also sometimes appears to involve the slowing down of particular rapid-learners who, by pulling ahead of their colleagues, have the effect of imbalancing the system. But managment also has a variety of other functions (described above) involving the eastablishment of procedures which affect the learning curve of particular operators.

figure 1

Simulated learning curves



But ultimately, as we have repeatedly pointed out, the productivity of the CAD system depends upon organisational changes in the system. including complementary adjustments in the other spheres of the firm, that is information control and production/ distribution. Without these, the full benefits of the CAD system cannot be realised. The time span within which management is able to comprehend the changes which are necessary, and then to implement them, is generally, but not always, longer than those involved in the individual learning curve. However there are, as with the operator learning curve, periods of flatness in the growth of system productivity.

Conclusions

On the basis of a detailed empirical investigation in the US and Europe it is clear that the use of CAD technology is essential in many sectors if firms are to compete in world markets. Since many of the benefits offered by CAD technology (reduced lead time, better quality products and reduced costs) are also to be obtained via the introduction of microelectronics in other sectors (eg machine tools and garments—see Jacobsson's and Hoffman and Rush's contributions), we believe that this represents a common pattern.

At first glance, as our more detailed discussion of the skill implications suggests, developing countries have few problems in mastering the use of the new technology. If anything at the level of operation (rather than back-up) microelectronics related innovations are easier to use than the craft-based systems which they replace. If this is so, it suggests that the major concern for developing countries over the coming decade lies in maintaining access to developed country markets in the context of growing levels of structural unemployment throughout the globe.

But on deeper consideration it is evident that whilst the absolute skill barrier to the use of CAD (and other microelectronics technologies) is slight, a close 'hand-holding' relationship between users and suppliers and between different users is absolutely essential for the efficient use of the technology. Consequently because of the established presence of CAD suppliers and systems in developed countries, it is likely that at least in the foreseeable future the technology will spread less rapidly to developing countries than to developed ones. It comes as no surprise, therefore, to learn that of the CAD systems surveyed in the wider study only 32 out of over 6,000 systems have gone to developing countries. And of these 32 most went to either TNC subsidiaries in the petroleum industry or to governments aiming to map their countryside (with USAID technical assistance) to assist in counter-insurgency programmes.

Therefore to the extent that CAD is representative of the use of microelectronics in industrial products and processes, we can anticipate that the diffusion of microelectronics will be associated with a reduction in developing country comparative advantage. This will not be a result of any absolute skill barriers to utilisation, but rather as a consequence of the close organic link required between suppliers and users, and between different users of radically new technologies. The origins of these technologies in developed countries make it likely that the new technologies will develop and diffuse more rapidly in these same economies.

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The role of computers in developing countries

Over ten years ago major studies were carried out by the United Nations into the role of computing in developing countries. Two reports were published, in 1970 and 1972, which analysed the then current state of development and identified the close relationship between computing capability and positive development. In 1978 a conference entitled 'Intergovernmental Conference on Strategies and Policies for Informatics' (SPIN) was held in Torremolinos. It was attended by some 80 nations, most of them from the developing world, and here the close relationship between computing and development was explored in depth.

In the original United Nations study four categories of computer development were identified. The first, which was called the Initial level, really covered those countries which had no effective computing capability of their own. Today such countries as Ethiopia, Lesotho and the Solomon Islands would come into this category.

The second, called the Basic level, is attained by countries which have clearly started upon the computer development road. They will have some significant use of computers in government and there will be education and training programmes in computer technology. This category would include such countries as Kenya, Nigeria, Egypt, Indonesia, Venezuela and Chile.

The third or Operational level defines the situation where computing is well established within the national environment. There will be a well identified education programme; major use of computing in government; design and production of software and maybe some hardware. Examples here are India, Singapore, Korea, Mexico and Brazil.

The fourth or Advanced level refers to those nations which are virtually capable of supporting themselves in computing terms, with fully matured design and production, professional and educational capabilities. This category would include the UK, the USA, Japan, Australia and a number of European countries.

The rate of computing development in the most industrialised nations is very advanced indeed, and we have come a long way in a mere 30 years since the early days of computing. The pace of development is still accelerating and the gap between the most advanced and the least advanced nations is widening. This gap can be analysed in a number of areas:

I. The systems gap

Successful implementation of computer systems is dependent upon there being a systems infrastructure on which to build. It is easy in advanced countries such as the UK to take this infrastructure for granted. For example, our taxation system works comparatively efficiently because it has built up over the years and because individuals, companies, banks, accountants and so on are accustomed to the procedures. Where these procedures do not exist or are inefficient, it becomes difficult if not impossible to devise a computer based system to meet the national requirement.

There is often resistance against the establishment of interdependent systems within a country which will take a very long time to be broken down at the existing pace of social change. Only by concerted national effort, sponsored by government, can the pace of change be accelerated to allow the benefits of systemisation to be attained.

II. The education gap

This is certainly the principal barrier to successful development and is at the root of the problems which developing countries face. For a country to move from the Basic to the Operational level of development implies an education programme on a national scale.

This means:

—a level of general education which will prepare the population to participate in a computer based culture. Sooner or later, directly or indirectly, all citizens will be in contact with the spreading

implementation of computer technology and will be intimately involved and affected by its applications;
—a level of general education which will provide a pool of trained minds sufficiently large to form a source of computer practitioners;
—a level of higher education which will mature the nation's computer scientists, computer professionals, and teachers;
—a level of management education which creates business, commercial and government environments where computer methods can be introduced:
—and finally, a level of technical education and training which can produce the systems analysts, programmers, operators and engineers who are necessary to develop, maintain and support the growth of applications.

III. The technology gap

It seems likely that the technology gap can never be bridged. The cost of setting out on a technological development path and catching up with the world leaders would be outside the capability of practically any nation. This does not mean that a country should not attempt to carve out a particular area of technological leadership, but there must in future always be some dependence upon the most advanced nations.

One major area where the developing countries may aspire to equality is in software technology. Certainly, the development of an indigenous capability in this area can be achieved far more quickly and far more cheaply than for hardware.

IV. The application gap

What are the applications which developing countries see as having priority? Certainly there is some common ground with the advanced countries, particularly in private industry and in government administration where the problems and the achievable benefits are of a similar nature. They are not the same, however, and this has implications for the transferability of software. Indeed the differences dictate the need for the development of indigenous software competence.

Almost certainly, it is in the public sphere that the real differences of priority exist between developed and developing countries and where they will be manifested. Examples of the sorts of activities which could be pursued are development and exploitation of natural resources. Many developing countries have immense resources available to them. They have an enormous task to turn the benefits from those resources into economic and social growth for the country as a whole. Programmes of work to achieve this require major support in planning, in project management and control and in scientific research and analysis. The resulting operational systems require continuing management. All these activities imply requirements for computer systems.

Raising educational standards. Many developing countries will have half their population under the age of 15 during the 1980s. Automated learning systems are needed to cope with the educational task.

Health care. Computers have already enabled major advances in raising the standard of health care for epidemiology and administration systems through the work of the World Health Organisation. There is further potential in this area.

Increasing food production. Raising output is a matter of improved agricultural methods, development of specialised strains, improved distribution and, above all, national planning. How do the developing countries see the priority here?

V. The power gap

As information systems develop and increasingly lie within the control of the most developed countries, particularly the USA, the developing nations are becoming increasingly concerned that their freedom to manage their own affairs might be eroded. The capacity to process information is fast becoming as valuable an international commodity as oil fuels, and the control of information is a major asset which nations would do well to guard jealously.

An illustration of this problem was quoted at the SPIN conference. The Brazilian representative reported that a factory in Brazil owned by a United States multinational has its production control system linked by satellite back to the parent company in the USA. In theory the parent company was in a position simply to turn the factory off if it so wished.

The United Nations report came to four conclusions about the role of computing in developing countries. These were:

> i) 'Computer technology will increase in importance in the developing countries and its diffusion and sound application can make a significant contribution in accelerating the rate of their economic and social development'.
>
> ii) 'Education and training for the application of computers to accelerate the process of economic and social development must receive first priority'. Thus, whilst the careful and judicious application of computers can speed up the process of national development, this can only happen if there is effective education and training first.

iii) 'Each developing country needs a broad national policy consistent with its national goals on the application of computer technology'. Obviously plans will look very different in different countries and they will depend on the current state of development, the general level of education, the higher education programme, the financial, industrial and human resources available, the status of the communications systems and the pressures of immediate priorities.

iv) 'International cooperation needs to be increased in activities relating to the application of computer technology to development'. The developing countries need help of all kinds to enable them to take advantage of world-wide computing development. It is up to the developed nations to provide support.

The United Kingdom as a source of technical assistance

It is clear that the UK has the experience and skills necessary to help the developing countries move into the information technology age. It has a mature infrastructure in computing which has developed over the last 30 years. It is possibly as advanced technically as any other country, and in some areas it leads the world. It has an educational system second to none, which at university level is nationally planned and coordinated and whose quality extends in depth to secondary level. It has a developed government machine for planning the use and development of computing in central government. It covers the full range of industry competence: hardware, software and services. The UK is also a major contributor to the establishment of international standards. The extent of user application is fairly comprehensive and sophisticated. The work of the National Computing Centre is known and highly respected throughout the UK and overseas, and the British Computer Society is one of the leading professional bodies in the world.

Whilst initiatives are taken from time to time, often in response to outside requests, for the UK to help and advise other countries in this area we do seem to have a marked inability to coordinate our resources. An example of the problem may be illustrated by referring to the visit of a UK delegation to Mexico City in 1978. The purpose of the visit was to hold a seminar on computing in the public sector for an audience of Mexican government technical and administration officials. The delegation was lead by HMG and included representatives of the UK services industry under the aegis of the Computing Services Association, ICL (the largest UK computer firm), the National Computing Council (NCC) and the British Computing Society (BCS). The intention was that we should impart useful and valuable information to the Mexican authorities and that this would be the beginning of a process of future cooperation. Whilst the conference engendered great interest amongst the delegates at the time, the event failed to achieve the objective of closer cooperation. I believe that the reasons for the failure of this mission were three-fold:

- a shortage of coordination and planning between the parties in preparation for the visit;
- a lack of direction and follow up by the UK Government, bearing in mind that government bodies are not normally empowered to take initiatives in this kind of activity;
- the industry participants believed that their investment in the mission was related to possible short term returns rather than long term investment requiring continuing dialogue and coordinated follow up.

The birth of the UK Council for Computing Development

The UK Council for Computing Development has been set up as a company limited by guarantee and having charitable status. It is funded by membership subscription and draws its expertise primarily from its members. Since the announcement of the formation of the Council in May 1981 most effort has been spent in seeking support from individuals and organisations for the proposal. As at the end of October 1981 some 70 individuals and 30 organisations have joined, providing both financial and technical viability. These organisations include a number of companies in the computing industry, users such as British Telecom and the Central Computer and Telecommunications Agency, universities and polytechnics and institutions such as the BCS, the NCC and the British Council. The Council is now operational and its immediate plans are to launch a major effort to publicise itself in the developing countries and the International Agencies, and to offer its services to those in need.

The Council will operate in two principle modes in its dealings with developing countries. It will tend to deal, in the first instance at any rate, with governmental or official bodies, and its main aim will be to establish a bilateral agreement with specific countries that the UK will help them in formulating a national computing policy and the computing development strategy that would arise from this. This in turn would lead to specific tasks such as the establishment of a national training institute, the formation of a national computing centre, setting up professional and technical standards, encouragement of an indigenous computing industry, curriculm development in education and maybe application work in areas of strategic importance to a country. In supporting these activities the Council will have a part to play in seeking funds from the appropriate development agencies with which it will have links of its own.

In addition to this major responsibility in respect of specific countries we may expect many requests from other countries for *ad hoc* support for particular tasks. The Council will respond to these as far as it is able within the limits of its resources.

Conclusion

The objectives of UKCCD should be seen in the context of policies in general. In the first place the aim is to help the poorer countries to help themselves, rather than to attempt to pour resources into the task of doing the job for them. In the second place the benefit should be mutual in the sense that the contributors will themselves gain in the long term from their contribution and participation. Whilst it is clear that industry participation is not going to result in the development of rapid business, most of the industry members see long term benefits to themselves in helping these countries to improve their effective and efficient use of computing, and to establish links which can be developed in the course of time.

Also, the speed at which modernization makes progress in China is of significance.

(7) In this context, it would be meaningful to come out with a number of scenarios on the future of the Asia-Pacific region with alternating changes in a number of premises, such as the speed of China's modernization. The author believes it is high time such scenarios be framed up, but again this is not a subject under the theme of this paper.

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THE ELECTRONICS INDUSTRY IN MALAYSIA — Issues in Transfer and Development of Technology —

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I. Introduction

Malaysia, as in many developing countries, is placing heavy emphasis on industrialization for two main reasons — to generate productive employment and, to diversify the economic base of the country to make it less dependent on exports of primary commodities such as rubber, tin, oil palm and timber. It also offers prospects of a transfer of technology which should lead to upgrading of skills and the quality of capital so crucial to economic development.

However, in more recent years, there has been increasing concern that the existing pattern of industrialization has not lived up to all its promises. First, despite the high rates of growth of industries, the generally capital-intensive nature of these industries has resulted in less than satisfactory rates of growth of employment. Secondly, whatever employment that is generated has exacerbated existing inequalities in income, and compounded the dualism already existing in the economy.[1] Thirdly, the transfer of often inappropriate technology from abroad has inhibited the development of local technological capability and therefore perpetuated technological dependence on the

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1. A concise account of why this occurred both within and between countires is given by Yotopoulos and Nugent (1976), Chapter 14. See also Adelman and Morris (1973) and Chenery and Syrquin (1975).

oped countries.[2] Further, there are economic costs associated with perations of multi-national corporations (MNCs), which have been iraged to establish as a result of the government policy of at- ng foreign investment.

The study of the extent of transfer of technology by these lishments and of their linkage with the local economy to Malaysia erefore very important, and because the electronics industry is led as a high-technology one and one dominated by MNCs and n-owned enterprises, it is appropriate that it has been selected as : study. Its choice is also justified by its size and phenomenal rate owth relative to other industries in the manufacturing sector[3] : 1). At the international level, Malaysia is after Singapore, the t exporter of electronics components and electrical goods.

n Section 2, major characteristics of establishments making up mple providing data for analysis are described. The methods and of transfer are dealt with in the next section, while the relation- between technology transfer and the development of local ilities via employment of personnel and research and development lored in Sections 4 and 5. Evidence on diffusion of technology h primary-ancillary linkages and through labour turnover is sed in Sections 6 and 7, and last but not least, major implications licy are drawn in Section 8.

II. Characteristics of Surveyed Establishments

his study is based on data collected from as survey of electronics ectrical companies in Peninsular Malaysia in August 1980.[4] A f 60 establishments was covered in the survey, and out of these, vided information on the transfer of technology and primary- ry relationships. Fourteen are wholly-owned subsidiaries of 10 are foreign-owned non-MNCs, and the remaining 8 are local shments. (Table 2).

a comprehensive discussion of the methods and effects of technology transfer, see ard (1979).

little of substance has been written on the Malaysian electronics industry. An early unt is Federal Industrial Development Authority (1971). The most comprehensive y is that of Lim (1978), while Lester (1981) examined specific issues in the transfer of nology.

study of the electronics industry is part of a large study covering six industries: les, cement, electronics, wood, plastics and steel.

Table 1

The Growth of the Electronics Industry, Peninsular Malaysia, 1973-1978

Indicator	1973	1974	1975	1976	1977	1978
No. of Establishments: No.	83	107	122	138	170	181
% Income	—	28.9	14.0	13.1	23.2	6.5
Value Sales: US$ Million	122.1	266.1	275.6	435.5	602.3	890.8
% Increase	—	117.9	3.6	58.0	38.3	47.9
No. of Paid Employees: No.	22,562	26,672	30,098	46,559	49,518	60,957
% Increase	—	18.2	12.8	54.7	6.4	23.1
Salaries and Wages Paid: US$ Million	11.9	26.4	28.9	47.1	65.8	87.7
% Increase	—	121.8	9.5	63.0	14.0	33.3
Value of Exports: US$ Million	11.0	86.5	116.8	204.8	345.4	652.5
% Increase	—	686.4	35.0	75.3	68.6	88.9
No. of Establishments as % Total No. of Establishments in Manufacturing	5.1	6.0	6.6	7.1	7.6	7.3
Value of Sales as % of Sales of Total Manufacturing	5.5	7.9	8.9	14.9	11.8	14.5
No. of Employees as % of Total No. of Employees in Manufacturing	12.4	13.7	14.2	19.2	18.8	21.0
Value of Salaries as % of Total Value of Salaries in Manufacturing	7.7	13.7	12.8	16.4	18.0	19.1
Value of Exports as % of Total Value of Manufactured Exports	2.3	11.1	13.9	19.1	27.1	36.3

Sources : Malaysia: Department of Statistics: *Monthly Industrial Statistics* and *Annual Statistics of External Trade, Peninsular Malaysia*

Table 2
Ownership and Nature of Production of Surveyed Establishments

Industry	Number of Establishments	Ownership	Nature of Production
ctronics MNC Subsidiaries	12	4 American	(3 Components (1 Industrial
		4 Japanese	(3 Components (1 Consumer
		1 Italian	Components
		1 German	Components
		1 British	Industrial
		1 Canadian	Components
reign	5	1 American	Components
		2 Japanese	(1 Component (1 Consumer
		1 French	Component
		1 Swiss	Industrial
cal	6	Malaysian	(4 Consumers (2 Components
ectrical MNC Subsidiaries	2	2 Japanese	(1 Consumer (1 Industrial
reign	5	1 Australian	Consumer
		1 Hong Kong	Consumer
		1 British	Industrial
		2 Origin Not Stated	(1 Consumer (1 Industrial
cal	2	Malaysian	Consumers

Electronics establishments are more labour intensive compared to electrical goods establishments; the component electronics establishments are the most labour intensive, employing an average of 966 workers per establishment. The capital investment of electronics establishments range from $0.32 million to $9.09 million as shown in Table 3. The range is smaller for electrical goods establishments ($0.46 million to $2.73 million).

Table 3
Employment and Capital Investment of Surveyed Establishments

Industry Group	Average Employment	Capital Investment (US$ Million)	
		Average Value	Range
Electronics			
Components	966	$2.84	$0.23 – $3.18
Industrial	657	$1.77	$0.32 – $5.91
Consumer	539	$3.41	$0.23 – $9.09
Electrical	339	$1.74	$0.46 – $2.73

III. Methods and Costs of Technology Transfer

The transfer of technology to developing countries can take various forms, depending on several factors, including the complexity of the product and production techniques transferred, the transfer environment in the donor and recipient countries, the absorptive capacities of the recipient firm, and the transfer capability and profit-maximizing strategy of the donor firm.[5] Generally, the transfer of technology may take the following forms: turnkey contracts, joint ventures, technology licensing agreement, management contracts and public knowledge.

In the early stages of a country's industrialization, most foreign enterprises usually adopt the turnkey arrangement where there is direct

5. See for example, Baranson (1970), Cooper and Sercovich (1971), Stewart (1979) and United Nations (1973; 1975).

and complete transfer of technology, from the plant construction stage to the production stage. In almost all cases the foreign companies themselves provide all the technical and managerial resources, by arguing that technological leadership and reputation for quality and efficiency cannot be maintained unless they have full control of the operation of the plant.

In recent years, joint ventures have been encouraged as an alternative to MNC subsidiaries. In effect, however, transfer of technology through joint ventures is almost similar to the turnkey method because the suppliers of process technology maintain considerable control over the operation of the new production facilities, since the local partner has limited technological and/or management know-how needed to organize the new project.

Where there is minority foreign capital participation in joint ventures, the transfer of technology may take the form of technology license agreements whereby the technology seller reaps substantial returns in the form of fees, royalties, and profits from the sales of components and intermediate products. From the buyer's point of view, a license is regarded as the quickest way of acquiring a given technology and as a means of establishing a monopoly position in that particular technological field.

Local entrepreneurs who wish to establish a manufacturing concern but do not possess the necessary technological know-how usually buy the patents or know-how from foreign manufacturers. In such cases, the foreign seller also takes charge of various phases of establishing an enterprise. Again, the local entrepreneurs usually have limited experience with licensing agreements and little knowledge of the technical implications and cost of the various parts of the technological package, and are therefore at a disadvantage vis-a-vis suppliers of patents when prices are negotiated.

A final source of acquiring technology is from suppliers of machinery and equipment or through technical and commercial publications (books and journals). Suppliers of machinery and equipment normally provide advice on the operational technology pertaining to such equipment, particularly where the technology is not very complex and where no proprietary techniques or processes are involved. In some cases, the machine supplier may even provide training for local personnel or continue to guide the plant operation beyond the normal start-up and take-over stage. Payments for such services may be provided for separately or are built into those for machinery and equipment. Usually it is the small locally-owned enterprise producing

standardized and technologically unsophisticated goods that rely solely on technical assistance from the suppliers of machinery. The medium sized and large local companies that produce highly differentiated branded goods tend to use license agreements.

Table 4 shows the major method of technology transfer used in the surveyed establishments. All the electronics and electrical MNC subsidiaries are turnkey projects, and it is not suprising that although most of them have been established since the mid-1970s, they are still heavily dependent on their parent companies for equipment and machinery parts, professional technical personnel, training of local personnel, and even marketing support. All the twelve electronics and two electrical MNC affiliates still rely solely on the parent companies for machinery, equipment, and spare parts; nine of them still depend heavily on the assistance of foreign professional technical personnel; and six of them send their local personnel for training in the parent companies.

None of the surveyed foreign establishment depend on the turnkey method of technology transfer. Of the ten foreign electronics and electrical establishments, five electronics and two electrical companies are joint ventures. All the five electronics joint ventures rely on the foreign partner for capital equipment, foreign professional technical personnel and training of local personnel overseas. Two of the establishments pay royalties (one for use of patents and one for technical assistance) to the foreign partner's parent company. The two joint-venture electrical establishments differ in their reliance on foreign partners. The Japanese establishment relies heavily on the parent plant i.e. it imports capital equipment, it depends on foreign technical personnel and its personnel are trained by the parent company. In addition, this establishment also pays royalty to the parent plant for the use of patents. The other electrical establishment, Australian-owned, obtains its capital equipment from its parent plant. It does not depend on foreign technical personnel and its local personnel are trained in Malaysia. However, it has to pay royalty to the parent company for the use of patents (brand name).

Three foreign electrical establishments obtain their technology through licensing arrangements. All these three establishments pay royalties to the parent plant for technical know-how and require the assistance of foreign professional technical personnel. In addition, two of these also pay royalties for the use of trade marks.

Seven out of the eight local establishments rely on licensing agreements [illegible] their [illegible]nol[illegible] the [illegible]inin[illegible] relying on [illegible]

Methods of Technology Transfer among Electronics and Electrical Goods Establishments

Type of Establishment	Total Number of Establishments	Transfer Arrangement: Turnkey	Licensing Arrangement	Joint Venture	Equipment Suppliers/Public Knowledge
Electronics					
MNC Subsidiaries	12	12	–	–	–
Foreign[a]	5	–	–	5	–
Local	6	–	5	–	1
Electrical					
MNC Subsidiaries	2	2	–	–	–
Foreign[a]	5	–	3	2	–
Local	2	–	2	–	–
Total	32	14	10	7	1

a: Defined as an establishment with over 30% foreign equity participation. The rest are classified as local.

Table 5
Average Cost of Technology Transfer among Electronics and Electrical Goods Establishments

Type of Establishments	Importation of Capital Equipment	Foreign Professional Technical Personnel	Training of Local Personnel Overseas	License Technical Know-how From Foreign Firms	Royalty Payments For Use of Patents
Electronics					
MNC Subsidiaries	1,574.1	126.4	109.1	–	65.5
Foreign	386.8	124.1	15.5	19.6	852.7
Local	36.4	6.4	–	22.7	45.5
Electrical					
MNC Subsidiaries	–	4.1	5.5	–	–
Foreign	95.5	35.0	44.1	34.6	76.4
Local	–	15.9	–	–	–
Total	584.6	59.6	48.2	28.2	198.6

knowledge as well as on equipment suppliers. Under the licensing agreements, one establishment pays royalty for the use of capital equipment, and another pays fees for engaging foreign professional technical personnel. The license arrangements for the other five establishments include contracts for the supply of capital equipment as well as foreign professional technical personnel. One of these also pays royalties for the use of patents.

Some of the establisnments surveyed provided data on money costs incurred by the methods of transfer described above. These costs are computed on a per establishment basis in Table 5. MNC subsidiaries in electronics spend on average much more on the imports of capital equipment than do other establishments. Foreign electronics establishments, with an average of US$386.8 thousand are a distant second. Overall, the next most important costs are royalty payments for the use of patents, averaging US$198.6 thousand per establishment. The bulk of this however comes from payments by foreign electronics establishments, averaging US$852.7 thousand. Consistent with other studies of technology transfer, costs associated with stationing of foreign personnel here and the training of local personnel are relatively unimportant. What can be noted, however, are the higher than average expenditures of foreign electronics firms for the former and MNC subsidiary electronics firms for the latter.

IV. The Employment of Foreign Personnel

It is impossible for Malaysia to develop electronics and electrical industries without importing foreign technology. However unless there is a concurrent development of local technical capability, the country will remain permanently dependent on the foreign suppliers, and there will be no opportunity to develop alternative technologies which are more appropriate in the Malaysian context. An important way to develop these is the training of local personnel to replace expatriate personnel in the establishments.

Table 6 shows the number of establishments which are still employing foreign technical personnel and the firms that are providing training programmes for the local personnel. As expected, all the fourteen MNC subsidiaries and nine out of the ten foreign establishments employ foreign technical personnel; in addition, six out of the eight local surveyed establishments also employ foreign technical personnel.[6]

Table 6

Technical Personnel in Electronics and Electrical Goods Establishments

Type of Establishments	Total Number of Surveyed Establishments	Employment of Foreign Technical Personnel	Training of Local Technical Personnel	*NO* Technical Training Programmes	*NO* Foreign Technical Personnel
Electronics					
MNC Subsidiaries	12	12	6	6	—
Foreign	5	5	5	—	—
Local	6	4	2	4	2
Electrical					
MNC Subsidiaries	2	2	1	1	—
Foreign	5	4	3	2	1
Local	2	2	1	1	—
Total	32	29	18	14	3

At the management level, however, foreign presence is only moderate. Table 7 shows that apart from Japanese establishments, with 9.2% of management personnel being expatriates, the representation of foreigners was small. One explanation could be differences in management methods[7], but differences in production activity may be just as important.

Table 7
Number of Expatiates in Management of Electronics and Electrical Goods Establishments: By Product Type and Ownership

Product Type/Ownership	Mean Number of Expatriates Per Establishment	Share of Expatriates in Management Personnel (%)
Product Type		
Consumer Products	5.4	7.8
Components	2.6	2.2
Industrial	3.0	7.9
Ownership		
Malaysian	3.5	6.0
Japanese	5.0	9.2
U.S.	1.5	0.8
European	1.5	4.3
Others	3.0	5.8

Although foreign technicians (mainly engineers) are costly[8], they are needed for various reasons. However, while the fact that almost half of the twenty-one establishments which responded state that the main reason is that their technical expertise is required suggests a shortage of local personnel with equivalent qualifications, only two establishments are explicit about this (Table 8). Nor were other reasons given entirely convincing. While four establishments list 'technological innovation required for new products' as a major factor, assembly operations are not known for product development. The same number state simply that company policy is responsible for this.

Table 8
Reasons for having Expatriates among Electronics and Electrical Goods Establishments

Reason	Number of Establishments	Percentage Distribution
Technological Innovation/New Product	4	19.0
Company Policy	4	19.0
Technological Expertise Required	10	47.6
Training of Staff for Eventual Transfer	1	4.8
Lack of Local Skill or Qualification	2	9.6
Total Responding	21	100.0

Significantly, half of the number of surveyed electronics MNC subsidiaries do not provide overseas training for their local technical personnel. On the other hand, all except one foreign electronics and electrical establishment do. Local companies also send their technical personnel for overseas training. Overseas training is normally for a short period of time – between one to six months at the parent plant or partner company. MNC subsidiaries spend between US$5,455 to US$127,272 a year for training locals overseas, while foreign establishments spend between US$22,727 to US$5,455 a year for such purposes. No corresponding data have been obtained from the surveyed local establishments. Only three out of the eight surveyed local establishments have overseas training programmes for their technical personnel. This is not surprising because, as mentioned earlier, most of these companies have acquired their technologies through licensing arrangements, and because most of the technical knowledge can be acquired from the suppliers of machinery and from the foreign profes-

6. An MNC subsidiary employs between one to thirteen expatriates while a foreign establishment has between one to nine foreign technical experts, and a local establishment employs between one to three foreign technical personnel.
7. See Kojima (1878).
8. The costs of maintaining expatriate personnel range from between US$49,091 to US$227,273 a year for MNC subsidiaries and between US$34,901 to US$454,546 a year for foreign-owned establishments.

sional personnel engaged by these companies, there is less need to organise overseas training courses for their technicians with a foreign firm also acts as a factor which hampers the training programmes of the local companies.

V. Research and Development Activities

Local research and development (R and D) is also essential to the development of local technology. A proper R and D base serves not only to adapt foreign technology but also to assist in its absorption and in its exploitation by further technical development.

Table 9 shows the extend of local R and D activities undertaken by the surveyed companies. Eleven out of the fourteen MNC subsidiaires are fully dependent on their parent plants in R and D work. In fact the R and D activities of all MNCs are located in the home country, with the results disseminated to their subsidiaries all over the world, partly because of the economies of scale in R and D work and partly

Table 9
Research and Development Activities of Electronics and Electrical Goods Establishments

Type of Establishments	Reliance on Foreign Source		
	Full	Partial	None
Electronics			
MNC Subsidiaries	9	3	–
Foreign	5	–	–
Local	4	2	–
Electrical			
MNC Subsidiaries	2	–	–
Foreign	3	2	–
Local	1	1	–
Total	24	8	–

because of the need to safeguard trade secrets. In three cases some design and development takes place locally but the basic research is still done in the parent plants. Foreign establishments are generally dependent on foreign sources in R and D work; eight out of the ten surveyed establishments are fully dependent on their partner companies, while two (electrical goods establishments) are partially dependent. The local establishments are heavily dependent on public knowledge such as journals as well as instructions from the machine manufacturers. The reliance on these sources indicates the generally low level of technology at which the local establishments operate, and the concentration on manufacturing products for which technology is widely known. The self-development of technology is costly and uneconomical for the relatively small local establishments while the lack of trained engineers and technicians also act as a deterrent. Nevertheless, three local establishments have some form of R and D work at a relatively low technological level (e.g. copying and modifying designs).

The primitive stage of R and D work in the electronics and electrical establishments in Malaysia is further indicated by the fact that even in establishments which have R and D, the amounts spent on such activities have been negligible. Expenditures on R and D range from between US$6,818 to US$27,272 a year. The number of staff engaged in R and D varies from one to twenty. Furthermore, as mentioned above the type of R and D is relatively simple. For example, a foreign electrical establishment is at present involved in the testing of automatic defrost (frost-free) refrigerators while a local electrical establishment acquires new technology by dismantling foreign-produced goods. Other R and D activities of the survyed establishments include the drawing up of new designs, research on quality improvement and adjustment of specification to local market needs (or to suit individual customer's tastes).

An analysis of the surveyed establishments regarding investment in R and D in Malaysia reveals the following: (a) when the establishment is only involved in the manufacture of some components for inclusion in an assembly, most of which has been imported from the parent plant or partner company, there is practically no investment in R and D; (b) where a foreign establishment establishes a plant in the country mainly to enjoy tariff protection, no R and D work is undertaken, the technology is simply transferred from the parent or partner plant with the minimum possible expenditure; and (c) establishments which are really interested in the long-term objective of producing for an expanding domestic market as well as a potential export market cons[illegible] it respondents) (Table 13). This includes, in effect, the local non-availability of materials able to meet the required technical specifications. The fact that four establishments cite the poorer quality of local materials was further evidence of this. Further Table 14 indicates that most establishments irrespective of product group are of the view that the products of local suppliers are poorer than those imported. Three establishments also report that imports are cheaper.

Table 11
Parts and Components Obtained from Local Ancillary Establishments

Type of Establishment/Ownership	Parts & Components
Electronics	
MNC Subsidiaries	Electrical Parts
Foreign	Packing Material; Plastic Parts; Polystyrene Parts; Printed Materials; Paint
Local	Resistors; Chassis
Electrical	
MNC Subsidiaries	TV Cabinets; Speakers; Packing Materials; Condensers
Foreign	Resistors; Plastic Cabinets; Antenna Coils; Packing Materials; Diodes
Local	Kettle Handles

The unavilability of supplies and materials locally suggests that an important way to improve buying arrangements of establishments is to set up more ancillary establishments here. The latter should, however, employ qualified personnel and, indeed, onç establishment would like to see better qualified personnel in existing establishments. Three establishments also feel that government duties on materials are excessive and should therefore be reduced.

Table 12
Relationships between Electronics Establishments and Local and Foreign Ancillary Establishments

Type of Establishments/Ownership	Number of Establishments: All Parts and Components Imported	Number of Establishments: Some Parts Obtained From Local Ancillary Establishments	Total
Electronics			
MNC Subsidiaries	11	1	12
Foreign	3	2	5
Local	4	2	6
Electrical			
MNC Subsidiaries	1	1	2
Foreign	4	1	5
Local	1	1	2
All Establishments	24	8	32

worthwhile to set up R and D work.

VI. Primary-ancillary Relationships

The transfer of technology involves not only its transfer from an investing (developed) country to the host (developing) country but also the diffusion of technology in the latter. One of the main arguments against free trade zones and the electronics industries of developing countries in the absence of linkages which bring about this diffusion.[9] We have attempted to test the validity of this hypothesis by identifying various linkages which may exist between local ancillary establishments. The responses from up to twenty-three establishments are presented in Table 10.

The lack of relationship is clear from this table. Only three out of twenty-three establishments invest in ancillary establishments, only two supply raw materials and two second personnel. At the same time, seven out of ten establishments report giving no assistance whatever to ancillary establishments which supplied materials while a similar percentage of establishments reports no plans for making arrangements with local ancillary establishments. Among the latter, the view is expressed by five establishments that arrangements may be made in future only if the technology of local ancillary establishments improves.

Parts and components supplied by ancillary establishments are listed in Table 11. While there is some variety in the range of products, most do not involve a high level of technology, and it certainly cannot be said that "the sophistication (of the ancillary establishment) is more advanced than the current domestic industrial sector could support on its own" (Lester (1981), p. 33).

The figures shown in Table 11, however, did not imply the lack of primary-ancillary relationships in general, as a much larger number of establishments had ancillary suppliers abroad. Table 12 shows that the majority of electronics establishments import all parts and components from abroad.

The majority of these cite the fact that these materials were not available locally as the most important reason for imports (84.6% of all

9. See, for instance, United Nations Conference on Trade and Development (1980). Lim (1978) came to the conclusion that "inter-industry linkages between multinational electronics firms and domestic supporting industries are non-existent in Malaysia and miniscule in Singapore so far . . ." (p. 464).

Table 10
Indicators Showing the Lack of Primary-Ancillary Relationship among Electronics and Electrical Goods Establishments

Indicators of Relationship	Type of Establishments (No.)				Total No. as % of Respondents
	Consumer Products	Electronic Components	Others	Total	
Investment in Ancillary Firms	2	1	0	3	13.0
Supply of Raw Materials to an Ancillary Firm	2	0	0	2	12.5
Personnel in Ancillary Firms	1	1	0	2	13.3
No Assistance to Ancillary Firms	3	3	1	7	70.0
No Increase in Ancillary Arrangements	9	1	2	12	66.7

Table 13
Reasons for Outside Purchases and Imports of Parts, Materials and Supplies Cited by Electronics and Electrical Goods Establishments

Reasons	Type of Establishments (No.)				Total No. as % of Respondents
	Consumer Products	Electronic Components	Others	Total	
Reasons For Outside Purchases					
Not Available Locally	7	7	1	15	78.9
Purchases of Parent Company	0	0	1	1	5.3
Better Quality	2	0	0	2	10.5
More Stable Supply	1	0	0	1	5.3
Reasons For Imports					
Not Available Locally	9	9	4	22	84.6
Cheaper	1	1	1	3	11.5
Pioneer Status	0	0	1	1	3.9
Total Number of Establishments	10	10	6	26	100.0

Table 14
Comparison between Foreign and Local Supplies to Electronics and Electrical Goods Establishments

Local Supplier is: —	Type of Establishments (No.)				Total No. as % of Respondents
	Consumer Products	Electronic Components	Others	Total	
Poorer	5	5	2	12	70.6
Equal	0	2	1	3	17.6
Better	1	1	0	2	11.8

VII. Mobility of Labour

Technology is diffused also by the movement of workers trained by electronics establishments. Evidence elsewhere again indicates that this is unlikely to be significant.[10]

Among the establishments surveyed, two factors make for diffusion along these lines. These are, as shown in Table 15, (1) a high proportion of workers 'trained on the job' in the plants, and (2) high levels of labour turnover and high vacancy rates. However, the first factor is less favourable than first appearance would suggest. The majority of the workers are reported to be trained on the job, while only an average 12.4% have been trained out-of-plant. It is likely that the 'training' provided to the former is low-skill, rudimentary, and often specific to the industry. Therefore, few skills are learned among unskilled and semi-skilled workers. A small proportion, the skilled workers, have been able to acquire some skills however.[11]

With respect to labour turnover, it was not possible to obtain quantitative estimates of the number of workers who have found work outside the electronics industry, but personnel officers in the surveyed establishments are almost unanimous in the view that most workers move within the industry. Also most of those who move are unskilled and semi-skilled workers, there being little evidence of the same degree of mobility among professional and technical personnel.[12]

VIII. Conclusions and Policy Implications

Despite arguments to the contrary, the general conclusion from this survey is that technological transfer among electronics and electrical establishments in Malaysia is extremely limited. Components

10. Cohen (1975) in his study of establishments in Korea, Singapore and Taiwan found that workers in MNCs tended to move between foreign firms so that skills acquired were not passed on to the domestic industrial sector (p. 111).
11. Lim (1978) came to a similar conclusion regarding the electronics industry in Singapore (p. 463). The opposite conclusion is arrived at by Lester (1981). He found that the vanity of job tasks performed was large, and "these job tasks and groups were not tied to the pecularities of the electronics industry sector but were widely applicable to any modern manufacturing sector" (p. 22). Since his sample consisted of technical personnel and skilled workers, however, his findings did not conflict with ours.
12. Lim (1978) goes even further, arguing that "on account of higher wages and better service conditions in MNCs vis-a-vis domestic establishments, there is even a possibility of personnel moving from the latter to the former" (p. 464).

Table 15
Qualitative Aspects of the Labour Force of Electronics Establishments: Training and Labour Turnover

	Percent of Workforce (%)			
	Consumer Products	Electronic Components	Industrial/Communications Equipment	Total*
Training				
On the Job, In Plant	65.7	98.2	87.0	81.9
Off the Job, In Plant	12.0	14.0	0.8	9.4
Out of Plant	11.9	3.8	23.6	12.4
Labour Turnover				
Recruitments	29.8	36.0	22.6	31.3
Resignations	20.3	28.6	22.5	24.9
Vacancies	19.8	9.7	13.3	13.1

* : Includes establishments classified under 'Others'.

establishments are largely 'turnkey' factories completely dependent on foreign technology, even though joint-venture agreements predominate among consumer products and industrial/communications equipment establishments. The direct monetary costs to the establishments of various forms of transfer are therefore minimal when compared with the value of sales. An exception is the cost of importing foreign machinery which is sizeable but to the extent that turnkey operations *necessitate* these imports, this strengthens rather then weakens our arguments about the absence of technology transfer.

This does not mean that economic costs to the host country of technology transfer are insignificant. The costs associated with actual royalty payments for instance represent but a fraction of other hidden costs like those associated with transfer pricing[13] (underpricing of exports and the overpricing of imports), restrictions on access to technology and other impediments to the growth of local technological capability.

The absence of research and development in the establishments surveyed is entirely consistent with the picture of lack of technology transfer discussed above. Complete or partial reliance on foreign (usually parent company) research resources, reported by a majority of surveyed establishments, strengthened the oligopolistic positions of multi-nationals as proprietors of technological knowledge and permitted 'packaging' of such knowledge by these companies when transfer takes place.

Further, the very limited linkages with local ancillary establishments also implied that transfer of technology via this channel is not significant. Among these ancillary establishments, most are engaged in the manufacture of low technology products or are machine shops. A third symptom of the lack of local skill or qualifications is the dependence on expatriate personnel. However, many of the surveyed MNC subsidiaries and foreign companies are providing overseas training for their technical staff, nevertheless, such training is only for a short duration of between one to six months at the parent plant or partner company. Most local companies however do not provide such training facilities.

While there has been widespread criticism of the activities of MNC's and their negative role in the transfer of technology, much has also been made of 'learning effects' or the transfer of 'general industrial

13. Stopford and Wells (1972) found that the extent of transfer pricing depended upon the type of enterprise in existence. Joint ventures paid less for inputs than did MNC subsidiaries (pp. 161-2).

experience' by these enterprises.[14] Data on these are hard to find, however, and our study does suggest that there be some learning effects in the electronics industry.

From the policy point of view, however, the crucial question is less whether these effects exist but more whether they could have been greater had other industries been established. More generally, it can be said that the issue of whether the transfer of technology is a major issue of government policy depends on the specific objectives of the policy. If the interest of the government is purely to maximize employment, then the electronics industry must be favourably considered. However, if, as is the case, the development of an industrial sector dynamic enough to generate appropriate technologies and possessing widespread linkages with other sectors is a principal objective, then the case for the electronics industry, particularly components assembly, cannot be a very strong one. Given, however, that present commitments to the industry cannot and will not be withdrawn in the foreseeable future, what policy options are available?

Various policies to improve the bargaining position of, and the benefits accruing to the host countries have been suggested. These have been classified into[15]: (1) those to control and improve the terms on which foreign technology is transferred, (2) those to promote local technological development, and (3) those to promote inter-industry linkages. Some of these have been implemented with varying degrees of success in industrialising countries.

In the case of Malaysia, however, dealings with foreign and multinational companies have so far been confined only to matters regarding tax rates or concessions, local equity participation, repatriation of profits, tariff protection, import quotas and so on. These is insufficient consideration regarding the types of technologies these companies will be introducing to the country and how these may be diffused, the decentralization of management decisions, participation in national research and educational activities and linkages with local industries.

Policy to encourage local technological development should include (1) measures to protect local technological development by allowing only selective import of foreign technology, and (2) provision of the required infrastructure and other incentives to encourage local

14. See Lester (1981) and Helleiner (1973). Kojima (1978) restricted this mode of transfer to Japanese enterprises, arguing that American MNC's, by producing goods which are technologically too sophisticated for the LDC's in which their plants are sited, do not permit much opportunity for learning.
15. Stewart (1979), p. v.

technological development. Under the latter, incentives may be given to establish R and D laboratories; fiscal incentives could also be given to a company to carry out research "cost-free". In addition, these R and D laboratories may be encouraged to deal with problems of the local environment, participate in local university research programs and enter into joint research with local research institutions such as SIRIM (Standards and Industrial Research Institute of Malaysia).

Realistically and in the short-run, however, the leverage of the host country vis-a-vis the MNC's may be quite limited, and the effectiveness of the suggested policy measures cannot be guaranteed. Over a longer period, as the country's industrial base is more firmly established, and as increasing incomes make for a larger domestic market, a shift in the types of industries to be encouraged will be desirable, indeed necessary, as Malaysia's comparative advantage in low wages is progressively eroded.[16]

16. An emergent labour shortage situation has already been reported in manufacturing. Population and labour force projections estimate that a general ageing of the population will become noticeable in the beginning of the next century.

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TECHNOLOGY TRANSFERS AND INTERNATIONAL COMPETITIVENESS: THE CASE OF ELECTRONIC CALCULATORS

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Abstract. International diffusion of production technologies, along with their creation, is increasingly recognized to cause dynamic changes in the pattern of international trade and investment. This paper seeks to develop a link between innovations, diffusions, and international competitiveness in electronic calculators in order to provide a greater understanding of this dynamic process. The major finding of the study is that changes in factor intensities were responsible for international migrations of electronic calculator technology between the U.S. and Japan. Another significant finding is that there is indeed an association between technology transfers and international trade.

INTRODUCTION

It is now generally accepted that international migration of production technologies causes dynamic changes in the pattern of international trade and investment.[1] Nevertheless, our knowledge in this area of economics is greatly limited. In the literature, there is a "paucity of clearly framed questions about technology transfer."[2] In fact, only recently have economists begun to pay serious attention to this important area of economic inquiry.[3]

The product cycle theory, by specifying a sequence of technology transfer dictated mainly by a gradual dominance of labor in the total production cost as the life-cycle of a product advances, provides the only theoretical framework for analyzing international transfer of technology. But in high technology-based products, which continue to undergo successive innovations, labor cost actually decreases as they begin to age toward maturity.[4] Furthermore, because of the minimization of the international "technology gap" in recent years, the underlying technology is often transferred from one country to the other before the product attains maturity, and sometimes the sequence of transfer becomes reversed. Thus, the product cycle theory is unable to explain fully the international migration of production location of many recently developed high technology-based products.

This paper deals with one such recently developed product. It attempts a case study of the electronic calculator industry with a view toward shedding some further light on the issue of international technology migration.[5] Through an examination of the changes in the product characteristics and their economic ramifications, the paper seeks to identify the factors contributing to the transfers of the electronic calculator technology between the U.S. and Japan.[6] The paper also investigates the effects of the transfers on the relative competitive positions of both the countries.

INTERNATIONAL TRANSFERS OF ELECTRONIC CALCULATOR PRODUCTION

The first transistorized electronic calculator was developed in the U.S. in 1962. The technology embodying the product was transferred to Japan through imitation in 1964, and the electronic calculator technology migrated back to the U.S. in 1971. Japan has again become the dominant producer of electronic calculators since 1975.

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TABLE 1

Relative Shares of Major Producers in World Calculator Production

Year	World Production in Percentages	Shares of Individual Countries in Percentages			
		United States	Japan	West Germany	Italy
1967	100	25	14	13	21
1968	100	22	40	13	20
1969	100	21	28	13	16
1970	100	14	41	10	16
1971	100	3	54	7	4
1972	100	20	50	5	7
1973	100	29	48	2	4
1974	100	30	44	2	2
1975	100	19	52	1	1
1976	100	19	56	1	0
1977	100	21	51	1	0

Source: U.S. Department of Commerce, "Industrial Outlook Report of the Business Machines Industry," various issues. Figures for 1975–1977 are obtained with the assistance of Mr. John McPhee of the U.S. Department of Commerce.

Note: Production data include electromechanical calculators. Although completely replaced later, production of electromechancial calculators continued until 1970 in the United States, West Germany and Italy. As a result, the figures understate the Japanese shares of the world electronic calculator production for the early years.

Transfers of technology are manifested in the shifts of location of production. Table 1 presents the data on the shifts of location of production of electronic calculators between the U.S. and Japan in terms of changes in their relative shares of world production. It also shows the relative contributions of other minor producers to the total world production.

For the purpose of analysis, the period covered by Table 1 can be divided into three distinct phases: 1967–1971, 1972–1974 and 1975–1977. The figures show that, after the Japanese imitation in 1974, their share of the world production of electronic calculators increased from 14 percent in 1967 to a peak of 54 percent in 1971. With this increase in the level of Japanese production, the American share decreased gradually, indicating a shift of location of production of electronic calculators from the U.S. to Japan during the first phase. The Japanese gain in production was also at the cost of other major producers. However, after 1971, the U.S. began to figure prominently again in the world electronic calculator production. The U.S. gain of dominance during the second phase was accompanied by a continuing decrease of the Japanese and other countries' shares of the world production of electronic calculators.

During the third phase, Japan again became the most dominant producer, accounting for over 50 percent of the total world production of electronic calculators. This Japanese gain coincided with the decline of the American share of production. It may be significant to note that the Japanese dominance continued in the third phase in spite of increasing level of production of the electronic calculator in the developing countries.

It must be pointed out that the Japanese imitation of the electronic calculator technology in 1964 occurred without any assistance from the original producers in the U.S. There were no licensing or joint venture agreements. The Japanese producers rather copied the product through a process of so-called "reverse engineering."[7] Furthermore, although the Japanese produced electronic calculators on a large scale during the first phase, they did so with semiconductor components supplied by U.S. firms. They designed "improved electronic calculators, utilizing much more complex integrated circuitry developed in the United States. Many of these integrated circuit components were also supplied by U.S. manufacturers."[8] Each of the major firms producing electronic calculators in Japan had "supply arrangements" with the American component producers.

PRODUCTION CHARACTERISTICS OF ELECTRONIC CALCULATORS

The transfers of the electronic calculator technology discussed above can be explained in terms of technical factors and their economic implications. However, to fully understand the factors that influenced the transfers, we first need to know what was involved in the production of the electronic calculator vis-a-vis its predecessor—the electromechanical calculator—and also how the production characteristics changed over time.

The electromechanical calculator—a so-called marvel of mechanical design and craftsmanship—was produced on a large scale in the U.S. and other European countries in integrated plants, employing a relatively capital-intensive production technique. By contrast, the development of the electronic calculator represented a radical change in the state-of-the-art and completely changed the skills requirement of calculator production. Unlike the electromechanical calculator, the electronic calculator was based on semiconductor technology, requiring the skills to design electronic circuits.

The electronic calculator was made of three main devices: an appropriate electronic circuit, a keyboard, and a display device. The building of the complete circuitry, which is the brain of the calculator, constituted the most important task in the assembly operation. The early electronic calculator circuits were built manually by using thousands of "discrete" semiconductor components; thus, labor cost was a dominant factor in the assembly of initial electronic calculators.

More significantly, because the early electronic calculators used standard semiconductor components—such as, transistors and diodes—one could become an assembler of electronic calculators without having to manufacture the components. This fact, coupled with the lack of scope for automation in the actual assembly, made the initial start-up cost of electronic calculator production low as compared with electromechanical calculators.[9]

Over the years, the electronic calculator went through several far-reaching technical transitions. In 1967, several thousand discrete components were replaced by less than 100 integrated circuits in the calculator circuits, which were later replaced by only four MOS/LSI chips in 1969. These innovations gradually decreased the labor content of the calculator assembly, and they were pioneered by the Japanese. However, the most important milestone in the calculator state-of-the-art was the development of the "calculator on a chip" by an American firm in 1971, which integrated all the necessary calculator circuit functions on a single, small MOS/LSI chip. This development made the assembly of units extremely simple, eliminating many intermediate steps, which significantly reduced the labor content of the assembly cost.

Another significant innovation was the development of the "calculator on a substate" (COS). The COS calculator, brought out again by the Japanese in 1973, was a "giant step toward complete system integration."[10] The development of the COS system made the assembly of electronic calculators even simpler, reducing the labor requirement for the assembly further.

FACTORS INDUCING THE TRANSFERS

The very innovation of the electronic calculator and the subsequent technical transitions had important economic effects. Table 2 presents these effects along with the relative hourly wage rates in the precision machinery industry of the U.S. and Japan. The data show first of all that the electromechical calculator and the

TABLE 2

Factor Intensities of Electromechanical and Electronic Calculators and Relative Wage Rates

Product	Year	Type of Components (Circuit)	Component/ Material Cost %	Labor Cost%	Overhead %	U.S. Wage Rate as % of Japan's Rate
Electro-mechanical	1964		21	23	56	504
Electronic	1964	Discrete	55	30	15	504
Electronic	1967	Integrated Circuit	56	28	16	389
Electronic	1969	4 MOS/LSI Chips	59	24	17	307
Electronic	1971	1 MOS/LSI Chip	68	10	22	237
Electronic	1973	COS	66	8	26	157
Electronic	1977	COS	65	5	30	80

Source: The factor intensity data originate from a survey conducted by the author during the Spring of 1976. The data for the electromechanical calculators represent unweighted averages of five largest U. S. companies, while ten U. S. companies are represented in the figures for electronic calculators. The wage rate data are from International Labor Office, *Yearbook of Labor Statistics*, various volumes.

early electronic calculators were produced with markedly different factor intensities. The proportion of total unit cost accounted for by labor was nearly one and one-half times as much in the case of electronic calculators as in electromechanical calculators. As a result, although the electronic calculator was developed in the U.S. to save human labor time in information processing tasks in the early years, its production characteristics in terms of relatively high labor share favored the Japanese, whose wage rate was less than one-fifth the American rate in 1964.

Because there were willing suppliers of necessary components among the American semiconductor firms, the relatively high labor content of the new electronic calculator provided a significant cost advantage to the Japanese, which induced the imitation.

The availability of the necessary skills to design and assemble final electronic products, using the discrete semiconductor components, facilitated the imitation. At the time of the imitation in 1964, a vast number of engineers and production workers with relevent skills, who were trained in the course of mass production of consumer electronic products—such as, transistor radios and televisions—were available in Japan. Another important source of designing skills was the Japanese computer industry.[11] In addition, under the provisions of the Electronic Industry Development Law, enacted in 1957 to foster the electronic industry, large numbers of engineers were trained to "reinforce the development of technical capacity."[12]

Another important factor that facilitated the imitation was that the Japanese were not major electromechanical calculator producers, so they had no "vested interest" and had little to lose by pursuing electronic calculator production.[13] Besides, the low start-up cost of electronic calculator production made the imitation easier.

Table 2 also shows that the factor proportions in the production of electronic calculators changed drastically over the years. With each innovation in the circuitry, the labor share of the electronic calculator cost declined gradually. The greatest saving of labor occured when all the electronics of the calculator were integrated on a single MOS/LSI chip. The new factor intensity was relatively more favorable to the U.S. wage rate. However, what was most crucial to the strong U.S. showing during the second phase was that the American firms pioneered this innovation.

Part of the reason why the production of electronic calculators shifted to the U.S. during the second phase at the expense of Japan was that the pattern of competition in the industry changed during that period. The American semiconductor giants—Texas Instruments, Rockwell International, National Semiconductor—became involved in calculator production during this period; thus those who were formerly suppliers to the Japanese calculator firms became their competitors.

With the introduction and further refinement of the COS system, the factor intensity of calculator production changed significantly again. The labor share became a smaller proportion (as low as 5 percent) of the calculator cost. The assembly of electronic calculators became a relatively automated procedure. This change in factor intensity in the third phase was advantageous to the Japanese since their wage rate in the precision machinery industry exceeded the American rate during the period. In addition, it was the Japanese who innovated the COS system, and they also attained self-sufficiency in calculator component production during the period. It was not surprising that Japan became again the single most dominant producer of electronic calculators in the third phase.

EFFECT ON COMPETITIVE ADVANTAGE

The transfers of the electronic calculator technology back and forth between the U.S. and Japan had significantly affected the pattern of competitive advantage[14] in electronic calculators. Table 3 presents the data on the relative positions of the two countries both in the American market—the largest single market for electronic calculators—and in the world market. The figures show a sharp contrast in the direction of trade in electronic calculators during the two phases.

The direction of competitive advantages seems to have paralleled the direction of migration of the electronic calculator technology. Although they started with a meager 17 percent of the market in 1967, the Japanese captured 67 percent of the total number of electronic calculators sold in the U.S. in 1969. Their share of the market increased even further during the next two years. By 1971, they supplied 80 percent of the American market. However, during the second phase, as a consequence of the migration of the technology, the U.S. became dominant in the domestic electronic calculator market.

The situation was reversed to a significant extent during the third phase. The proportion of the American market accounted for by the Japanese increased to 40 percent in 1976 from 25 percent in 1974; however, the Japanese share declined again in 1977. This decline is perhaps attributable to the sharp appreciation of the yen with respect to the dollar in recent years. In addition, the imports of electronic calculators from Japan have in recent years faced increased competition from similar products from developing countries, such as Hong Kong and Taiwan.

The computed export elasticities, which compare the individual country's export performance with the world imports, show a similar pattern. When the Japanese were capturing an ever-increasing share of the American market, their export elasticity was high, indicating their strong competitiveness worldwide. When the Japanese were losing the U.S. market to the domestic producers, Japan's export elasticity coefficients were low, whereas the U.S. coefficients were significantly higher than one. Thus, the pattern of competitive advantage in electronic calculators has shifted drastically as the underlying technology has migrated.

CONCLUSIONS AND IMPLICATIONS

A country may decide to foster a foreign technology for many possible reasons, all of which may not be economic, but there must be strong economic incentives for the country's individual economic agents actually to adopt and disseminate it quickly. The most important factor that induced the Japanese firms to imitate the electronic calculator was that the factor intensities of the early electronic calculators were relatively more consistent with the Japanese factor supply advantage—that is, cheap labor. Japan had the necessary skills to take advantage of this favorable situation. They also did not have a large electromechanical calculator industry to create a "vested interest" against the adoption. The absence of a domestic source of supply of components was not a major obstacle. Similarly, the development of the single-chip calculator by the American firms, which caused significant saving of labor, was a crucial factor in helping the U.S., with its relatively higher wage rate, attain dominance in electronic calculators. A similar explanation is applicable to the Japanese dominance following the innovation of the COS calculator. Thus, it can be concluded that as innovations changed the input requirements of the electronic calculator, the country favored by this change became the location of production.

It has been found also that there is indeed an association between technology transfers and international trade. When the electronic calculator technology migrated from the U.S. to Japan during the first phase, so did competitive advantage. The same pattern held true when the technology migrated from Japan to the U.S. in the second phase. The third phase shows an almost identical relationship. In other words, the dynamic competitive advantage in electronic calculators was determined by the pattern of technology migration. This finding confirms the hypothesized connection between technology migration and international trade, as expounded by the so-called "new theories" of trade.

Although the study presents a special case, it has implications for the recent demands of the American producers of consumer electronic products—such as,

TABLE 3

Pattern of Competitive Advantage in Electronic Calculator

	Relative Performance in U.S. Market			Relative Performance in World Market	
Year	U.S. Consumption %	U.S. Share %	Japan's Share %	U.S. Export Elasticity	Japan's Export Elasticity
1967	100	NA	17	NA	NA
1969	100	NA	67	NA	4.4
1970	100	17	79	1.0	2.5
1971	100	18	80	1.0	3.2
1972	100	39	56	3.1	1.6
1973	100	45	36	2.1	0.9
1974	100	50	25	1.0	0.8
1975	100	39	37	0.8	1.5
1976	100	34	40	0.5	1.3
1977	100	45	29	0.1	0.9

Sources: Data for 1967–1974 relating to the performance in the U.S. market originate from the U.S. International Trade Commission, *Electronic Calculators: Workers of the Action, Mass. Plant of BowmarlAli, Inc.*, Report to the President on Investigation No. TEA-W-250, TC. Publication 703 (Washington, DC, 1974). Elasticity coefficients for the years 1967–1974 are computed from the data reported in U.S. Department of Commerce, "Industrial Outlook Report of the Business Machines Industry," various issues. Data for the years 1975–1977 were obtained with the assistance of Mr. John McPhee of the U.S. Department of Commerce.

NOTE: The concept of export elasticity is defined as: $\frac{x_1 - x_0}{x_0} \Big/ \frac{X_1 - X_0}{X_0}$ where x represents the individual country's level of electronic calculators export and X stands for the total world export of the product. Subscripts 0 and 1 represent the years compared.

television sets—for protection from imports. The increased imports of these products may represent a short-term phenomenon, which may be reversed quickly by long-term forces of technology, as has happened in the case of electronic calculators. Thus, attempts to influence the technical forces rather than tinkering with protectionist measures may be a more fruitful course of action from a long-term point of view.

It may also be interesting to note that the product cycle theory, which is a dynamic theory of comparative advantage, cannot adequately explain the transfers of the electronic calculator technology. Unlike the sequence specified by the theory, the Japanese imitation of the product took place long before the product became mature. Besides, the American gain of dominance in electronic calculators during the second phase was in response to decreases in labor intensity as opposed to increases, as postulated by the product cycle theory. In addition, the experience of the electronic calculator industry indicates that the technology migration process may not, after all, be unidirectional, as the product cycle theory would have us believe.

FOOTNOTES

1. For example, Johnson argues that "the essence of the dynamic theory of comparative cost is the international migration of production." In Harry G. Johnson, *Comparative Cost and Commercial Policy Theory for a Developing World Economy—Wicksell Lectures 1968* (Stockholm: Almqvist and Wicksell, 1968), p. 31.

2. Richard E. Caves, "Effects on International Technology Transfer on the U.S. Economy," in National Science Foundation, *The Effects of International Technology Transfer on U.S. Economy* (Washington, DC, 1974), p. 38.

3. For the Arlie House Conference on Transfer of Technology held in 1966, Professor Jan Kamenta was assigned to make a survey of "what economic theory had to say about transfer of technology. Finding that economic theory had little to offer," he had to develop his own theory for presentation at the conference. Daniel L. Spencer and Alexander Woroniak, *The Transfer of Technology to Developing Countries* (New York: Praeger Publishers, 1967), p. 2.

4. For example, see Badiul A. Majumdar, *Innovations, Product Developments and Technology Transfers: An Empirical Study of Dynamic Competitive Advantage* (Washington, DC: University Press of America), forthcoming.

5. Contrary to the neoclassical tradition, I define the term "technology" as the knowledge about a product (or process) and the means through which it can be produced (or implemented).

6. Richard Caves, "Effects of International Technology Transfer," p. 37, recently suggested such a methodology:

> Channels of technology receipt. . . . We have plenty of casual evidence on this question, but it is capable of systematic investigation. One attractive design would be to compare a given industry in several countries. . . . that have apparently used different channels to ingest it . . . Because the technology is not an easily measured flow, I suspect that only a painstaking analysis of cases would be feasible.

7. The Congressional Record documents that

> All Japanese companies benefited greatly from the years of expensive research and development work done by the American companies. . . which had produced the first electronic calculators. Since there was little by way of patent protection, the Japanese were able to use the early American commercial units as models.

U.S. Congress, House of Representatives, 92nd Congress, Second session, *Congressional Record*, p. 13549.

8. U.S. International Trade Commission, "Calculators, Typewriters and Typewriter Parts," Report to the President on Investigation No. TEA W-140, TC Publication 492 (Washington, DC, 1972), p. 11.

9. U.S. Congress, *Congressional Record*, p. 13549.

10. Atushi Asada, "Calculator's Parts are Integrated on a Single Glass Sub-Strate," *Electronics*, 6 February 1975, p. 109.

11. Japan was the only country besides the U.S., the Soviet Union, and the UK to have a domestic computer industry. See U.S. Department of Commerce, *Japan: The Government-Business Relationship* (Washington, DC, 1974), p. 78.

12. The Electronic Industry Development Emergency Law (EIDEL) was enacted in 1957, when Japan as a matter of policy decided to develop the indigenous electronic industry.

One original purpose of the EIDEL was to increase the domestic skills base. See Ministry of International Trade and Industry, "Commentary on the EIDEL," June 1970 (mimeographed).

13. According to U.S. Congress, *Congressional Record*, p. 13549:

> The Japanese who had never been factors in the mechanical rotary or printing calculator business, were not held back—by large inventories and investment in that business. Thus, the Japanese were able to make a complete commitment to electronic calculators without concern for pre-existing products or business.

14. The term "Competitive advantage" is used here to distinguish it from the concept of "comparative advantage." For the distinctions, see Badiul A. Majumdar, "Innovations and International Trade: An Industry Study of Dynamic Competitive Advantage," *Kyklos*, Fasc. 3 (1979), p. 560.

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WORKING PAPER ON RESEARCH AND TECHNOLOGICAL CAPACITY FOR THE USE OF RENEWABLE ENERGY RESOURCES IN DEVELOPING COUNTRIES

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This Working Paper is the main document for the meeting of the World Bank's *ad hoc* advisory committee on renewable energy research November 19-21, 1980 at Airlie House, Va. It was prepared by Charles Weiss (Science and Technology Adviser), Jean-Roger Mercier, M.A.S. Malik and David J. Cantor (Consultants), Pradeep Bhargava and Fernando Manibog (Researchers), and Amarquaye Armar and Kishore Mandhyan (Research Assistants). We thank Richard Dosik (New Energy Sources Adviser), David Hughart (Energy Department Staff) and Paulo Krahe, Peter Hammond, Russell de Lucia and Peter Rogers (Consultants) for helpful comments. Richard Herbert (Consultant) edited the manuscript. Questions and comments should be addressed to Charles Weiss, Room E1036, Telephone No. (202) 477-6525/6.

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WORKING PAPER ON RESEARCH AND TECHNOLOGICAL CAPACITY FOR THE USE OF RENEWABLE ENERGY RESOURCES IN DEVELOPING COUNTRIES

Abstract

The twin energy crises posed by the increased price of fossil fuels and the threat of deforestation confronts the developing countries with a major technological challenge. As an urgent necessity, they must mobilize technology for the use of renewable energy resources. In doing so, they must surmount the obstacles presented by a fast-evolving field which offers a broad range of technologies of varying sophistication, many of which were developed to meet needs other than their own.

Yet the rewards are significant. Improved renewable energy technology can do more than save scarce foreign exchange by replacing increasingly expensive fossil fuel imports. It can also help meet the development needs of the poorer majority through energy applications that are more efficient and appropriate, as well as being less costly.

This report examines the needs not only for research on renewable energy technology suited to the individual conditions of developing countries, but also for building technological capacity in those countries to assess needs and resources, and to choose, adapt, create and diffuse renewable energy technology suited to their needs. It concludes that developing countries would derive major benefits from increased investment in these two key areas. It accordingly outlines a global strategy to this effect.

It recommends that existing bilateral and multilateral assistance to national programs in renewable energy technology be expanded and reoriented

towards increased emphasis on building local technological capacity. It further recommends that new international programs be undertaken (i) to diagnose the needs for technical assistance to strengthen national scientific and technological capabilities for renewable energy development (ii) to support research on biomass production technology of particular interest to developing countries and (iii) to facilitate the transfer to developing countries of advances in renewable energy technology made in industrialized countries and in other developing countries.

Specifically, these new programs would: assist developing countries to diagnose needs for building local scientific and technical capacity for renewable energy needs and resource assessment, research and development, technology assessment, demonstration and diffusion; improve technologies for producing biomass from familiar crops (sugarcane, cassava, sweet sorghum) and investigate the potential of familiar and novel species for biomass production on nonagricultural land; and develop reliable data on the performance of renewable energy technologies for the production of heat, mechanical and electrical energy, evaluate experience in different countries with such technology, and make global assessments of likely future technological developments and their implications for renewable energy use in developing countries.

This report proposes the first outline of this major international initiative. It is the main document to be considered by the Ad Hoc Advisory Committee on Research and Technological Capacity for the use of Renewable Energy Resources to be convened by the Energy Department of the World Bank November 19-21, 1980. A suitably revised report will be prepared thereafter. This revised report will contribute to discussions preceding the United Nations Conference on New and Renewable Sources of energy, to be held in Nairobi in August 1981.

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WORKING PAPER ON RESEARCH AND TECHNOLOGICAL CAPACITY FOR THE USE OF RENEWABLE ENERGY RESOURCES IN DEVELOPING COUNTRIES

I. INTRODUCTION

A. Background

1.01 The increased price of fossil fuels confronts the developing countries with a major challenge. As an urgent necessity, they must mobilize technology for the use of renewable energy resources. 1/ In doing so, they encounter three obstacles. First, they are faced with a fast-evolving field, as renewable energy technology was neglected in favor of fossil fuel technologies during the years of cheap petroleum. Second, they must choose for a broad range of applications, from technologies that vary in sophistication from photovoltaic cells to clay stoves and village fuelwood lots. Third, many of the rapidly changing technologies they must become acquainted with, and match to their needs, were developed to meet needs other than their own.

1.02 These obstacles are surmountable. And renewable energy will do more than save scarce foreign exchange by replacing increasingly expensive fuel imports. It will help meet the development needs of the poorer majority, by providing energy in forms that are not only less costly, but also more efficient and appropriate for their needs.

1/ Renewable energy is used in this discussion to mean an energy form, the supply of which is partly or wholly regenerated in the course of the annual solar cycle. Thus solar and wind energy, hydropower, and fuels of vegetable origin are regarded as renewable; mineral fuels, geothermal, wave, tidal, and nuclear power are not. Large hydropower installations also are excluded from the analysis. The line between renewable energy technology and conservation technologies has been somewhat arbitrarily drawn: specifically, wood stoves are considered, but passive solar architecture is excluded.

1.03 Where will the technological advance required for these practical applications of renewable energy in developing countries originate? Much of the impetus will stem from the efforts of public or private companies in industrialized countries. These companies are responding to the new energy economics by using modern materials and established engineering principles to improve neglected technologies, as well as to develop new technologies.

1.04 To speed this advance, several industrialized countries (and a few developing ones) have encouraged research, development, demonstration, and commercialization of renewable energy technologies and applications. These activities have taken place in both government institutes and in the productive sector. 1/ They range from the applications of well known principles of science and engineering to explorations at the frontiers of knowledge. The policies and programs involved are concerned mainly with sophisticated technologies to meet the industrialized countries' own needs. Once these technologies are proven, they will become available to the developing countries through normal commercial channels. Moreover, advances in such fields as the hydrogen economy, photosynthesis, and fusion could have major long term effects on energy use throughout the world.

1.05 Experience shows, however, that imported technology seldom matches the needs of developing countries. It requires major changes in scale, and extensive adaptation to suit local conditions. This is true even for the modern sector of developing economies. Many of the technologies which do have the greatest potential use in the developing countries have only been minimally tested in these countries. In any event, such technology is

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1/ The productive sector refers to that part of the economy, whether privately or publicly owned, which produces goods and services.

frequently beyond the resources of poor people in developing countries. Their special needs are unlikely to attract investment in innovative technology from the private sector.

1.06 For these reasons, many of the technologies needed in developing countries will be developed or adapted locally or will be transferred from other developing countries. In order to bring about the widespread application of these technologies in developing countries two significant steps are needed — advances in, or adaptation of, these technologies; and the building of the capability within the developing countries to undertake these advances and apply them effectively. This involves competence in engineering and in both natural and social sciences. It includes the ability to assess needs and resources. It requires the skills to choose, adapt, and create the necessary technologies, and the ability to establish appropriate institutions for their manufacture, commercialization, and distribution.

B. Role of the World Bank

1.07 The World Bank has responded to the needs of its developing member countries as the urgency for this use of their renewable energy resources has become apparent. It constituted a Task Force on Renewable Energy in December 1979 "to consider the Bank's role in the development of renewable energy and to recommend an action program for Bank lending and activities in the years immediately ahead." The findings of the task force were summarized in the report on "Renewable Energy Resources" distributed to the Executive Directors of the Bank on July 31, 1980. 1/

1/ SecM80-593.

1.08 The work of the task force also contributed to the Bank policy paper "Energy in the Developing Countries" (August 1980). This report emphasized the fundamental importance of planning institutions, extension and delivery systems, and research programs for the mobilization of renewable energy resources. It points out (p.41) that progress in exploiting renewable energy potential "can easily be hampered by the lack of a coherent national energy plan within which the role of renewable energy can be defined, priorities among the various technologies determined, and resources assigned — especially when programs to develop renewable energy sources begin to require important policy and budgetary commitments. To use these resources on a wide scale will require extension and other delivery systems that are capable of reaching the urban and rural poor with technical and social assistance and credit facilities." The report further suggests (p.42) that "... attention needs to be given to strengthening national research programs and to the possibility of organizing international programs of research on specific renewable energy technologies."

C. Organization of the Report

1.09 The remainder of this report is divided into three sections. The first assesses needs for building a local capacity for mobilizing renewable energy technology in developing countries. This theme is treated first because the crux of the challenge is not the technological hardware itself, but rather the capacity and ability to identify problems and match solutions to them. After a brief overview, the section reviews the present state of national capacity and the scope of bilateral aid programs. It concludes with a series of recommendations. The second section addresses the need for research and assessment of an extensive list of technologies relevant to the needs of developing countries. It first reviews the agricultural technologies for biomass production and their applications, and then technologies for generating heat, mechanical and electrical energy. It ends by proposing new international programs. The third section summarizes the report's recommendations and possible institutional arrangements for implementing these programs.

II. BUILDING CAPACITY IN DEVELOPING COUNTRIES FOR MOBILIZING RENEWABLE ENERGY TECHNOLOGY

2.01 Because the scope of the field is so wide, some degree of local technological capacity in renewable energy is within the reach of every developing country. Some of these countries are planning and implementing major integrated multisectoral programs for the exploitation of renewable energy resources. They aspire to manufacturing and export capacity and leadership in technologies, such as fuel ethanol, requiring an industrial and professional base. Other countries may find it more appropriate to concentrate on adapting and diffusing simpler, less expensive technologies, such as cooking stoves and biogas.

2.02 The World Bank report on "Renewable Energy Resources" stresses (para 3.27) the two important roles of national research programs: "In the first place, [they are] a vital part of the technology transfer/absorption mechanism in that they enable developing country scientists and technologists to acquire direct working experience with the new technologies. And, second, they enable the developing countries to acquire the technical ability to adapt imported technologies to the local environment and to improve on traditional local technologies."

2.03 The full range of technological capacity needed to mobilize renewable energy technology in developing countries is very broad. Resources need to be surveyed and needs assessed. Industrial technology has to be reviewed and selected. Agricultural and industrial research must be undertaken. Technologies have to be developed, demonstrated and extended, and steps taken to assure their local manufacture, commercialization, and diffusion. Also to be addressed are the technological and sociocultural elements of policymaking involving renewable energy resources, and this includes establishing incentives for their use. Further, renewable energy considerations must be integrated into a broader energy policy and into policymaking in such sectors as agriculture, industry, urban development, and transport.

2.04 This comprehensive technological capacity should animate institutions ranging from those of the scientific and technological infrastructure — universities, government laboratories, extension services, and the like — to the engineering groups of private or public sector manufacturing firms, and consulting and engineering organizations. Also involved will be nongovernmental organizations active in community development; resource survey groups; analysis divisions of energy or planning ministries; and private individuals. Particularly significant will be achieving the proper balance between efforts to stimulate technological innovation and adaptation and efforts to diffuse technology and encourage its use.

2.05 The effective mobilization of renewable energy technology depends on cooperation and synergy among these organizations and individuals, as well as on political commitment. The precise form of this cooperation will depend on a specific country's objectives; on its social and cultural traditions; on its financial, material, and human resource base; on the level of its overall development; and on the technologies it needs to use. For example, local cadres in China have taken major responsibility for the design and implementation of projects for biogas, small hydropower installations, and village fuelwood. National and provincial organizations are responsible for advanced training, research, and the planning and coordination of the technological development involved. In Guatemala, India, and Sri Lanka, informal voluntary organizations with an intimate understanding of local problems have made important contributions to biogas projects and to improved cooking stoves. The Brazilian national program on fuel ethanol, by contrast, is centrally managed by the federal Ministry of Industry. The national petroleum monopoly, several national laboratories, private research centers, and a large number of manufacturing organizations are all involved.

2.06 The worldwide response to the new energy era is at an early stage. Not every country can employ the full range of capacities needed to mobilize renewable energy. A start must nevertheless be made. The integration of technological capacity with policymaking in the renewable energy field, and of renewable energy with overall energy problems is desirable, but may be more than can be realistically handled at this stage. Few if any developed or developing countries have achieved this objective. Developing countries should nevertheless strengthen linkages between their renewable energy development efforts and overall energy planning and demand management activities. To date, renewable energy development has often been neglected in the formulation of overall energy policy.

A. Present State of National Capability

2.07 Virtually every developing country is attempting some improvement in its use of renewable energy resources. These activities range from major investments to a few uncoordinated demonstrations. A preliminary review of the capabilities of 19 countries for mobilizing renewable energy technology indicates that the countries concerned can be placed in three broad groups.

2.08 The first group of countries demonstrate the highest level of institutions, technical skills, expertise for social analysis, and policy commitment for renewable energy. The next group show a relatively recent policy commitment but only a limited capability, or conversely, some capability but no policy commitment. The third group have a minimal policy commitment and a low level of capability. Their activities are limited to a few projects, both technical skills and the mechanism for the diffusion of renewable energy technology are limited, and there is little coordination among the few institutions or individuals showing initiative in this area.

2.09 In the first group of countries, the policy commitment to mobilize renewable energy technology is generally high. There is a strong, or a rapidly emerging, scientific and technological community, supported by adequate facilities. These countries have a substantial manufacturing base and there exists a degree of synergy among the organizations concerned with renewable energy technology.

2.10 One of these countries has effectively diffused biogas, small hydropower, and village fuelwood systems throughout its rural areas. It has done so as part of an overall development strategy which emphasizes building local self-reliance, technological infrastructure and decision-making and innovative capacity. Another has concentrated on the development of alcohol fuels, an area in which it is a world leader, but it also has capabilities and programs in other areas. Two others pursue research and diffusion programs in virtually all areas of renewable energy. Another employs policies that encourage renewable energy applications. It has established a large number of research, manufacturing, and training institutions dealing with renewable energy technology. Senior personnel are limited, but the government has an aggressive program to attract back skilled emigres. Still another country, though not as advanced as others in this category in terms of manpower and infrastructure, has a framework for research, manpower training and diffusion of technology.

2.11 The second group of countries has concentrated on relatively simple technologies. The policy commitment of these governments to the use of renewable energy resources is leading to the creation of an infrastructure, of human resources, and of appropriate policy and institutional mechanisms. Most of these countries lack technical personnel and rely on expatriates for their senior staff. In one country the need to develop strong organizational and project management skills in public sector organizations was identified as critical to further progress. Some countries have a large number of entities working on renewable energy, and are in the process of formulating policies to establish linkages among them. Others have a good research and manufacturing capacity, but need to develop their capability to perform surveys and energy assessments. Others have a concrete plan, but lack the financial and technical resources to implement it. Accordingly, commercialization and diffusion mechanisms have not yet fully evolved in these countries. They have achieved a reasonable degree of informal cooperation at the working level, but lack a mechanism to insure the continuity of renewable energy projects or the consistency of such projects with broad national objectives.

2.12 The third group of countries lacks an institutional framework for formulating policies and programs for the development and diffusion of renewable energy technologies. Activities are limited to a few uncoordinated projects. A few countries in this group have virtually no indigenous capacity for either research or diffusion. The few active projects that are being undertaken in the countries are managed and executed by expatriates. There is no evidence of a coordinated attempt to develop and exploit renewable energy resources. In two oil exporting developing countries, renewable energy resources have been given low priority, and the skilled manpower potential has not been tapped. As a result, even the limited activities pursued at universities and other research centers are isolated and fragmented. In another oil exporting country, skilled scientific researchers are working on a few projects with well equipped facilities, but there is no apparent interest in diffusion or commercialization of renewable energy technology or equipment. In two other countries, the research effort is uncoordinated and not linked to the productive sector for diffusion and commercialization. Both these countries have recently begun to develop an energy plan.

B. Review of Bilateral Aid Programs

2.13 Programs of bilateral aid for the development of renewable energy resources are relatively new and still evolving. A review of eight such programs reveals an orientation towards the demonstration of hardware developed in the laboratories and enterprises of the donor country. 1/ Some donor countries have attempted to use aid to create export markets in the developing countries for their own solar industries. Most of the research is still done in the home country. The technologies are not designed with a view to suiting developing countries' conditions. On the contrary, project conditions are chosen to display and test the technologies under favorable circumstances.

2.14 As a consequence, not much attention has been given so far to the analysis of end-use needs, the development of local capability to undertake research on the technological, social and economic impact of renewable energy resources, or to plan for the widespread utilization of these technologies. The creation of local institutions and mechanisms for marketing and commercialization of renewable energy technologies has also been neglected. What is more, the demonstration projects have tended to become ends in themselves. They have not been subjected to the extensive testing, evaluation, and adaptation that could lead to a widespread use of the technologies within the country.

2.15 Several of these aid programs are being reoriented to remedy these deficiencies. A small but increasing degree of support is being provided

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1/ See "Policies and Programs for Renewable Energy Assistance in Eight Development Agencies: Summary and Critical Evaluation" (T. Bartlem and R.T. Hoffman). The eight programs are those of US, UK, France, EEC, Germany, Canada, Sweden and the Netherlands. The aid programs examined are at widely different stages of development and exhibit considerable differences in emphasis. Some agencies are already well advanced in organization, in funding, and in the ability to meet changing circumstances and to assist in institution-building and training. Others have yet to formulate a renewable energy strategy and to form a staff. Some have had substantial experience in simpler agriculture- and forestry-based technologies, while others are providing leadership in more advanced solar-industrial technogies. While some agencies have developed an extensive technical and social data base, few have collected useful economic data from their field operations. This lack of data has precluded an economic analysis of how much their test technologies would cost as compared to other alternatives.

for local manufacture, for cooperation with local scientific and engineering institutions, and for the training of local energy analysts (mostly in the donor country). All the agencies studied share the growing realization of the importance of building local research and institutional capacity. In most cases, however, this concern has yet to be translated into concrete action.

2.16 Bilateral agencies and foundations tend to be inadequately informed as to what their colleagues are doing. They could benefit from a systematic exchange of information, including interagency meetings. Topics involved could be the overall level of efforts of each agency in each country and in each technology, as well as information on project plans and experience. This process should have a threefold impact. It would enable the agencies to learn from each other's experiences, to avoid duplication of efforts, and to agree on priority areas for aid activities. Ideally, in-country coordination is the task of the recipient country and indeed is an element of local capability. The purpose of coordination among donors would be to make this task easier.

C. Recommendations

2.17 The needs of countries for external assistance in developing their capacity for the use of renewable energy resources depend on two factors: the level of the capacity that already exists, and on the technologies and institutional arrangements best suited to their needs and conditions. Against this background, the recommendations that follow first consider the three groups of countries already described, and then address broader needs, including new institutional approaches.

2.18 The first group of developing countries have substantial programs for development of at least a few kinds of renewable energy resources and, in several cases, a record of successful manufacture of internationally competitive equipment. Equally important, they have achieved a degree of synergy among different programs and at least the beginnings of coordination with policy-makers. Several of these countries have done this with little or no outside help. In their fields of competence these countries can relate to the world scientific and technological community as full members or even as leaders. They can collaborate with their peers in other countries, define their own needs for expert assistance, and offer assistance to other developing countries less advanced in these fields. In these countries, needs for international cooperation are likely to involve advanced training, the expansion of existing infrastructure, and funds for research, development, engineering, demonstration and market development. The funds would be channeled both to government institutes and to the private sector, and would include measures to facilitate international collaboration with national researchers. Measures to encourage the transfer to and mastery of imported technology in the private sector may also be needed, as well as measures to facilitate joint ventures and other suitable business arrangements between domestic and foreign firms.

2.19 The second group of countries have recognized the potential importance of renewable energy. They have made a start, in most cases a small one, toward launching a balanced program and policy reasonably consistent with their equally limited overall energy efforts. These countries, in most cases, need external assistance in formulating and executing policies and programs. They also need help in developing a manpower and institutional base. If such assistance were offered, these countries would be expected to respond favorably, as they are in the early stage of building their capability.

It is particularly important that investment and demonstration projects in these countries be planned and implemented in such a way as to maximize the building of local capacity. Close linkages between research, development and demonstration programs and the productive sector should also be encouraged.

2.20 Awareness of the potential importance of renewable energy technology is very low in the third group of countries. Research, development and demonstration activities are confined to laboratories, frequently in universities, which are isolated from potential users. In such countries, official interest and support might best be attracted by a dual approach. This would combine, on the one hand, policy studies projecting energy needs and the available resources and technologies, and, on the other, a program aimed at selecting, adapting, and diffusing a particular renewable energy technology to meet some major national need. Such programs can be effective only if they carry through all stages of the innovative process. The sequence includes the identification of a need, the selection and adaptation of a technology, and commercialization and diffusion, at least on a pilot or, preferably, on a semicommercial scale. If this process were successful, it would be followed by international support for broader technological infrastructure programs in renewable energy, including appropriate diffusion mechanisms.

2.21 In most developing countries, whatever their level of involvement in renewable energy, there is a need for a substantial training effort. This should cover broad multidisciplinary training of energy planners, training in specific technologies, and training of professionals for whom energy is not a primary concern, such as irrigation or transportation specialists. There is a particular need for short courses to inform energy planners who were trained only in conventional technology, of developments in, and potentialities for, the use of renewable energy.

2.22 There should also be an effort at the national level to collect the technical and socioeconomic data needed to formulate national policies on renewable energy. A helpful tool is to establish the pattern of energy demand and supply. Simple models can then be applied to provide different scenarios for judging the overall impact of renewable energy technologies. Patterns of village energy use should also be studied.

2.23 Assistance in the building of broad local capabilities should be an important objective for both the bilateral and multilateral development assistance agencies. Such efforts should encourage cooperation among developing country scientists and organizations in the frequent cases when this is appropriate to the task at hand. Indeed, renewable energy provides a particularly fertile ground for technical cooperation among developing countries. This is because much of the information that is of the most interest to one such country is derived from the experience of others.

2.24 Development assistance agencies should also ensure that their projects give due emphasis to the development of local capacity: (i) to assess needs; (ii) to evaluate the appropriateness of technologies to address those needs; and (iii) to choose, adapt, create and diffuse suitable technology.

2.25 Investment projects for the large-scale application of proven renewable energy technology should be undertaken in such a way as to promote the building of local technological capacity and the linking of that capacity to the social and economic needs of the country. This development of local capability is a normal aspect of the operational work of the Bank and many other development assistance agencies, but it deserves special emphasis in the case of renewable energy technologies. In some cases adaptation of policies and procedures within the aid agencies may be required. This would accommodate the need to plan and to monitor closely the spending of relatively small sums of money for critical capacity-building undertakings.

2.26 Technical assistance for the development of capacity to utilize technology for the use of renewable energy resources seems particularly suited to grant financing, there is a critical need to maximize the availability of grant financing for this purpose. However, it is unrealistic to expect that sufficient international grant financing will be available to meet all such needs and developing countries should not be reluctant to use loans for this purpose if necessary, and if their creditworthiness permits, in view of the potentially high returns to investments in the strengthening of their scientific and technological capabilities.

2.27 Existing bilateral and multilateral aid donors can provide financial and technical assistance to aid local research, development, demonstration and diffusion capabilities. However, to set the stage for such assistance, special efforts are required to diagnose needs country by country, and to assist in the elaboration of national plans of action for developing technological capability for utilizing renewable energy resources. Practical constraints, such as emphasis on promoting the export of hardware developed in the donor countries and, in some cases, the lack of experienced staff, make it difficult for bilateral agencies to undertake a comprehensive review of the needs of a country and to prepare an action plan. Multilateral agencies like the World Bank and the regional development banks have also found it difficult in practice to allocate staff and other resources to deal adequately with the diagnosis of the needs of a country to develop local capabilities.

2.28 There is, therefore, a need for an international program to assist in the diagnosis of the priority needs of particular countries for assistance. Such a program would help in the preparation of a plan of action for the development of local capabilities, including proposals for technical assistance. But it would not normally extend to the actual implementation of that plan. This would be the task of existing bilateral or multilateral developmental assistance efforts. The scope of this international program of diagnostic assistance would be thus analogous to the assistance to the development of national capabilities in agricultural research to be rendered by the newly established International Service to National Agricultural Research (ISNAR) of the Consultative Group of International Agricultural Research (CGIAR). 1/ Such diagnostic assistance should be available for a wide range of technologies. It will frequently require close cooperation with existing agencies, such as FAO and UNIDO.

2.29 The program, in producing its diagnoses, will thus serve an integrative function that can help donors orient themselves to building capacity in developing nations. It may be useful to convene meetings to use the results of the diagnoses to facilitate the coordination of the efforts of bilateral and multilateral donors.

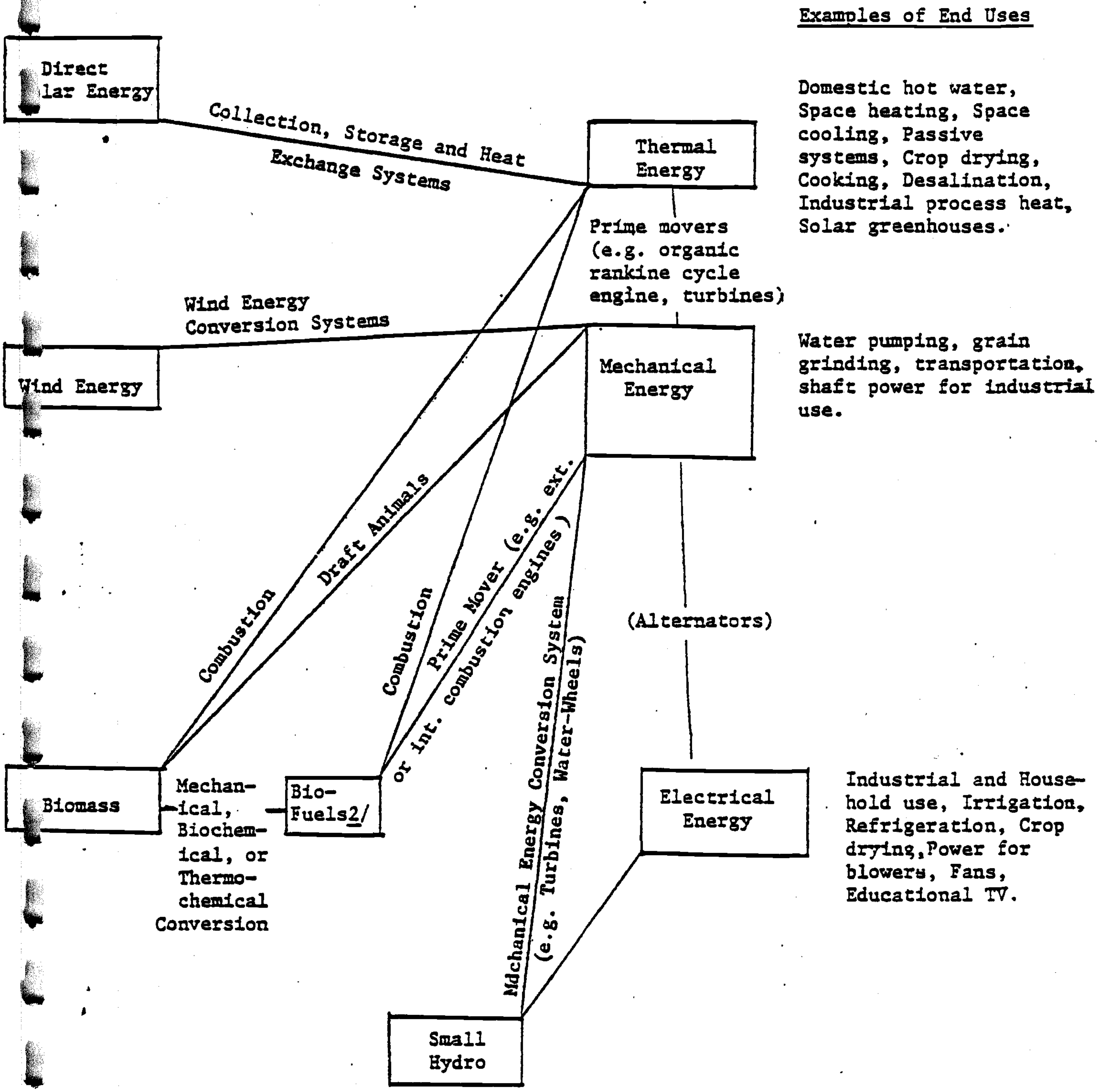
1/ ISNAR was established to fill the gap between the work of the international programs funded by the CGIAR and that of national programs of agricultural research. ISNAR will maintain an international staff that will provide technical assistance in the diagnosis of national needs for agricultural research and in the preparation of plans of action and proposals for technical assistance. The implementation of the plans would be funded by bilateral or multilateral sources. The German technical assistance organization (GTZ) has been designated by the CGIAR as executing agency with the task of launching ISNAR, and staff is now being recruited.

III. RESEARCH AND ASSESSMENT OF RENEWABLE ENERGY TECHNOLOGIES ORIENTED TO THE NEEDS OF DEVELOPING COUNTRIES

3.01 The major applications of renewable energy technology in developing countries involve cooking, transport, water pumping, lighting, crop and animal production, food processing and preservation, industrial process heat, health, and communications. They all require usable energy in one or more of the following forms: thermal energy, mechanical shaft power, and electricity. Figure I summarizes the pathways for conversion of renewable energy resources (biomass, solar, wind, and hydro) into each of these forms of energy. Mobile mechanical power, for example, may be provided by engines powered by biomass-based fuel, by draft animals fed by biomass, or by human pedal power. Renewable energy technologies may be used individually or in combination with each other or with fossil fuel technology. For example, wind electric conversion systems can be used individually or in combination with solar or diesel powered generators.

3.02 Of the energy resources summarized in Figure I, biomass merits special consideration because of its versatility. Biomass is storable and transportable. At least in principle, it can be converted into any usable form of energy and into a substitute for any petroleum or coal product. Mobile mechanical shaft power, for example, may be provided from four sources: by vehicle fuel derived from fermentation of biomass sugars to produce ethanol (to be used straight or mixed with gasoline), from destructive distillation of wood or agricultural residues to produce methanol, from gasification of wood or agricultural residues to form producer gas, or (in the future) from conversion of cellulose from wood or agricultural residues to ethanol. The production of biomass can be undertaken in any developing country at small

Figure 1: MAJOR RENEWABLE ENERGY RESOURCES AND APPLICATIONS FOR DEVELOPING COUNTRIES



1) Briquetting, digestion, fermentation, destructive distillation, pyrolysis. (See Table 2.)

2/ Briquettes, biogas, ethanol, methanol, charcoal, producer gas.

or large scale. Indeed, the burning of wood and animal and agricultural residues is the major source of energy for poor people in many developing countries today.

3.03 The technologies which carry out the transformation of renewable energy resources into usable forms of energy, except for the production of biomass, take the form of industrial processes and equipment. Equipment for some of the more sophisticated of these technologies — photovoltaics, large scale wind electric conversion systems, destructive distillation of wood — can only be developed and manufactured in the industrialized countries, or in some of the more advanced developing countries. Most of these technologies, however, are relatively well-known. In most developing countries they can be adapted to local conditions and manufactured by the industrial sector, or, in the case of simple, village-level technologies, by private organizations working closely with artisans and small workshops.

A. Review of Technologies and Applications

3.04 We have briefly but systematically reviewed the agricultural and industrial technologies for the use of renewable energy resources. Five factors were taken into account. These were: their present and attainable economics and performance; the benefits to be expected from innovation or diffusion of the technology in question; the likelihood of these benefits being obtained in practice; the prospects of investment of resources from private interests or bilateral aid agencies in their improvement and diffusion; and the ability of individual developing countries to carry out the necessary research, development, demonstration, and diffusion without external assistance. From this review, there emerges a tentative list of requirements for national and international action in research, development, assessment, and evaluation of technologies as they apply to the conditions and needs in developing countries. Prospects for agricultural technology and biomass production are assessed first, followed by technology for the production of heat, mechanical and electrical energy. Specific recommendations are then presented, including those relating to new international programs and to institutional arrangements.

1. Agricultural Technology: Biomass Production

3.05 Many developing countries are well endowed with biomass but its production for energy purposes can conflict with agricultural requirements. This puts a premium on the development of biomass production technologies suited to lands that are unattractive to food or cash crops, such as arid or saline soils, swamps and steep slopes. Such technologies should also, preferably, be labor-intensive and adaptable to small farms.

3.06 Biomass energy sources may take the form of wood, straw, oil, sugar, or cellulose. They may be derived from trees, shrubs, oilseeds, grasses, roots or field crops. Of the technologies for producing biomass, the only ones technoeconomically ready for immediate implementation are the growing of trees for wood fuel, and the growing of sugarcane (and, to a lesser extent, cassava and sweet sorghum) for fermentation into ethanol. Technology for producing vegetable oil from oil palm and sunflower is also in hand. The technology for using such oil routinely as diesel fuel, however, is still to be mastered. Finally, large quantities of straw and other agricultural residues are currently wasted or used inefficiently as fuel. With improvements in harvesting and densification technology (e.g., briquetting, pelletizing) more of these materials could be used more efficiently for energy purposes.

3.07 The report "Biomass Production Technology: Current Status and Research Needs," by R.A. Yates reviews the present status of, and main trends in, research in technology for biomass production, apart from the growing of trees for wood. Yates recommends both research on those biomass crops already in widespread use and efforts to identify crops that could be more attractive in the longer term.

3.08 According to the Yates report, sugarcane research goes back more than a century, and its agronomy is well known. Additional effort is required to collect genetic material. A new breeding program should be started with a view to maximizing the total biomass. The technoeconomic potential for harvesting the total biomass of sugarcane should be evaluated. Research on cassava, by contrast, is recent, although the agronomy for this crop is well-known. It stems largely from the interest of CGIAR in its role as a subsistence crop, especially in drought-prone areas. Existing research on cassava, although aimed mostly at subsistence agriculture and the production of starch for industrial purposes, is equally relevant to biomass production. However, additional effort is needed to collect cassava germ plasm, particularly in Mexico. Cassava culture frequently depletes the marginal soils on which it is found, and gullying can be particularly severe on marginal slopes. If intensive large-scale plantings are to be considered, then special attention should be paid to research on soil conservation systems. Sweet sorghum is a third crop suited to production of sugar for fermentation into fuel ethanol. It is now grown commercially on a limited scale in a few southern states of the United States. Despite its promise, there has been little research on sweet sorghum in the United States. Research on the crop in Brazil began only in the last few years. Genetic material should be collected. Field trials should also be carried out in areas where a short growing season gives this crop an advantage over sugarcane.

3.09 Yates recommends that research be begun on a number of promising alternative raw materials for ethanol production, including buffalo gourd, carob and tamarind. These crops have received relatively little research attention. They need to be planted for comparative yield evaluation vis-a-vis possible alternatives, including oilcrops and forest crops. They may have advantages over sugarcane or cassava for special ecological conditions. In particular, the potential of the sagopalm for saline swamps is probably sufficiently great to warrant the installation of a pilot plant; a feasibility study is required.

3.10 The situation with hydrocarbon-producing crops is similar. The agronomy of some crops (notably oilpalm and sunflower) is well advanced; other crops have only been identified. Assuming that tests prove that these oils can be used as a diesel replacement, then pilot processing units can be installed for the better known plants. For the lesser known plants (and especially for those suited to arid environments), comparative yield trials are required. Unfortunately, the literature is severely lacking in information about the water consumption of the arid-land plants. All work on these plants must include an evaluation of this factor.

3.11 The exploitation of straw and dry, wild grass requires the testing and selection of suitable harvesting and briquetting equipment rather than research. Censuses of the quantities of materials available are also required. They would be used, first, as combustible fuels; at some later stage, when the technology is developed, these materials may be converted to other forms of fuel. Research is also required to determine whether other plants are suitable for use in the same way as straw and wild grasses. Examples include cultivated grasses (including sugarcane) and saltbushes; in all cases, extraction of the protein-rich sap should be a feature of this work.

3.12 Very preliminary research is required to determine whether field trials would be justified on other plants. Namely, a survey of the major herbaria is required to identify novel plants; some plants which have been identified (such as Babacu, Caryocar, Copaiba, and Jessenia) should be checked to determine whether their yield potential justifies field trials.

3.13 The most promising species identified in the Yates report are described briefly in Table I. 1/

3.14 Research in treegrowing in tropical areas has traditionally been directed toward selection of provenances 2/ suited to pulp and paper production, and to a lesser extent to erosion control and other aspects of soil and watershed management. In the past few years, researchers have shifted their attention. They now focus on the need for fast-growing trees for fuelwood (biomass) production, either for forests for village fuelwood lots, or as part of farming systems for smallholders. A number of useful new species have been identified and tested on a large scale, notably Leucanae (giant ipil-ipil). Such tests should be continued, expanded, and integrated with other branches of research on the production of biomass energy. The forestry profession is strongly convinced that research on growing trees is best suited to national institutions which are closely familiar with local soils and environmental and social conditions. The Commonwealth Forestry Council is coordinating tests of promising species and provenances. As a

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1/ See also R. Revelle, "Flying beans, botanical whales, Jack's beanstalk, and other marvels," in The National Research Council in 1978 (National Academy of Sciences, Washington, D.C., 1978).

2/ A provenance is a source of planting material, e.g., a particular geographical area.

Table 1: PROMISING BIOMASS PRODUCERS OTHER THAN TREES

	Use	Species	Advantages	Research Needs
[Cr]ops Producing Readily Fermentable Carbohydrates				
Sugar crops with residual fuel	Ferment into ethanol using residual fuel for processing energy	Sugarcane	Well-known, throughly researched production technology; tolerant of poor soils; relatively efficient converter of solar energy; sugar production and fermentation self-sufficient for fuel.	Collection of genetic material from China-Assam-Burma Triangle; breed and test varieties and establish cultivation regime for maximum biomass; centralized service for recording, processing and disseminating varietal data; machinery and system to harvest total biomass
		Sweet Sorghum	Efficient converter of solar energy; shorter growing season than cane.	Little experience outside U.S.; (research in Brazil just beginning) field trials needed in areas where sugarcane cultivation difficult because of cold winter or prolonged dry season. Germplasm collection.
Starch crops with residual fuel		Sago Palm	Tolerates saline swamps; high yields.	Define agronomic requirements; breed for earlier maturity and higher starch content; try to harvest earlier; use more incident light in early years.
Starch crops with little residual fuel	Ferment into ethanol external energy source required	Cassava	Widespread crop under subsistence conditions on poor soils; drought tolerant; self-storing underground.	Increase yields under non-subsistance regime; soil management under large-scale cultivation; intercropping system with legumes to maintain soil fertility.
		Buffalo Gourd	Combination oilseed and starchy root; yield apparently very high; native of arid lands; vine is ruminant feed.	Test against possible competitors in a wide range of ecological environments; check evaporatranspiration requirements.
		Carob	Grows in Mediterranean climate on rocky soil with no other use; agronomic requirements well documented.	Test under similar conditions in other regions.
		Tamarind	Drought resistant; grows on poor rocky soil	Collect germplasm in Sub-Sahelian Africa; test best Indian varieties under similar conditions elsewhere
		Tania, Taro	Tolerates swampy conditions	
[Ce]llulosic and ligno-cellulosic (woody plants)	Direct combustion (e.g. cooking fuel, dendro-thermal power plants) digestion into biogas; fermentation to methanol/ethanol.	Straw	Available in vast quantities	Resource assessment; estimate of opportunity costs from other uses (e.g. animal feed); develop harvesting, handling and briquetting regime and technology at various scales and degrees of mechanization; product analysis; cost analysis (studies in each of several countries). Species and variety selection for grasses.
		Grasses	Efficient converters of energy	
		Saltbush (Atriplex)	Tolerate very high salinity	Possible protein producer.
[H]ydrocarbon Producing Plants				
With minor residuals	Diesel fuel	Euphorbia (Milkweed, Gopherweed)	High genetic potential	Little research to date.
		Neem	Traditional crop in India	Agronomy and selection almost non-existent.
		Castor	Oil can be used as diesel fuel	Little research to date; work beginning in Brazil.
		Jojoba	Tolerates aridity, salinity, high-value oil	Irrigation requirements; commercialization of oil for cosmetics, pharmaceuticals.
With residual fuel		Oil Palm	Well-known, throughly researched technology. Uses land unsuited to foodcrops; extraction self-sufficient for fuel; smallholder production often successful.	Comparision with other crops for biomass production potential; test as diesel fuel (no special agronomic research required).
Also producing protein		Safflower) Sesame) Sunflower)	Agronomy well-known; extensive breeding has been carried on sunflower; sunflower oil is reported to be used on a commercial scale as diesel fuel.	Technology for refining oil for regular use as diesel (no special agronomic research required),
		Buffalo Gourd	See above.	

[So]urce: R. A. Yates, "Biomass Production Technology: Current Status and Research Needs," (July 1980) first step in identifying needs and priorities for international action, FAO is surveying the present activities of national forestry laboratories and their view of research priorities.

3.15 New approaches to the growing of trees — such as short harvest times and close spacing — are blurring the lines between the discipline of forestry and the study of other forms of biomass, such as shrubs and grasses. An important objective of biomass research is to evaluate all forms of biomass suited to a particular ecological condition according to common criteria. This is to enable farmers and competent local authorities to select the system best suited to their needs.

3.16 Another promising line of research is into the use of the leaves of leguminous 1/ trees, of which Leucanae is an example, as a source of fertilizer in small farm systems. Such research would seem to be a high priority for national agricultural research laboratories and for the international agricultural research centers funded by CGIAR. We have not in this report considered the needs and opportunities for basic research on the mechanisms and the ecology of biological nitrogen fixation. Such research is relatively inexpensive and is well suited to universities and research institutes in developing countries.

3.17 These lines of research all present to the scientific community the challenge of stimulating communication, collaboration, and cross-comparison among all workers concerned with biomass production, whatever their disciplinary origins or institutional affiliations, and between them and the general agricultural research community.

1/ Leguminous trees, like other legumes, have nodules on their roots which harbor symbiotic bacteria that fix nitrogen from the air. They are therefore net contributors of nitrogen to the soil.

2. Technology for Production of Thermal, Mechanical and Electrical Energy

3.18 Apart from those involving biomass production, technologies for the conversion of renewable energy resources can be divided into those for the processing of biomass into usable fuels, on the one hand, and those for the production of thermal, mechanical and electrical energy, on the other. Many of these technologies will be developed and supplied by the modern sector of industrialized and developing countries. Other simpler and smaller-scale technologies are suited to manufacture and maintenance by small workshops and artisans in villages and small towns in developing countries after suitable local adaptation.

3.19 Research into, and the development and commercialization of, modern industrial sector processes and equipment is advancing rapidly in industrial companies in developed countries. It is also taking place in a few relatively advanced developing countries. In both instances, government participation in, and support to, such research is a major element in national programs.

3.20 A major problem facing planners and prospective users of these renewable energy technologies in developing countries is that of making informed choices among competing processes and equipment. This task is made more difficult by the absence of agreed standards, quality criteria, and evaluation methodologies. In many cases, it is compounded by the absence of reliable performance data under conditions typical of developing countries.

3.21 This lack of reliable performance data and evaluated experience is particularly acute in the case of simple, village level technologies, such as cooking stoves and sail windmills. Some less sophisticated technologies, such as windpumpers, can be manufactured in the productive sector in most developing countries, sometimes with external technical assistance. On the other hand, the commercialization of such technology frequently does not offer sufficient incentives to private industry.

3.22 The research into, and the engineering and diffusion of, these technologies has mostly taken place in small, private organizations in developed and developing countries. These organizations are often closely in touch with the needs of the poor in the particular place where they work. But they are underfunded. They are also relatively isolated from each other, from the local scientific and technological communities, from the government, and from the mainstream of the economy. Such "appropriate technology" organizations can and should continue to play an important role, consistent with their capabilities. They are in need of relatively small sums to facilitate research, collaboration, communication, and development of agreed evaluation methodologies. With some exceptions they are, however, incapable of managing the problems of large-scale diffusion of these technologies.

3.23 The technologies for processing biomass into convenient fuels are classified in Table 2. Almost all of these transformations may be carried out in large, modern installations or with simple, small-scale equipment suited to use at the village level.

3.24 Other nonagricultural technologies for the use of renewable energy resources are summarized in Table 3, which classifies technologies for producing low, medium, and high temperature heat; for stationary and mobile mechanical shaft power, and for generating electricity. In the case of low temperature heat, the technology for solar water heating is well known, widely diffused, and amenable to local manufacture in many developing countries. The demand for large quantities of hot water is, however, relatively limited in most developing countries. It primarily originates in hospitals, restaurants, and hotels; in the homes of the relatively well-to-do; and in industrial processes, such as food processing. Low temperature heat is also needed for crop drying, an application for which solar technology is already available.

3.25 The solar pond is a promising technology for the production of low temperature heat. This is a large, shallow pond sealed with a black, impermeable substance and filled with brines of increasing concentration, with the densest at the bottom. The black layer absorbs the sun's energy and transfers it to the bottom layer of brine, which may reach 100°C without mixing by convection because it is still heavier than the layer above it. First developed in Israel (with partial funding from the World Bank), solar pond shows considerable promise.

3.26 The technologies for production of medium and high temperature heat involve those for cooking, on the one hand, and those for industrial process heat and electricity, on the other. Traditional technology for cooking with biomass fuel -- a pot supported over a wood, charcoal, or cowdung flame by three stones -- makes inefficient use of increasingly scarce and expensive fuel. Experience in parts of the developing world demonstrate that groups closely in touch with local people (particularly women) and their cooking needs can design more efficient cooking stoves that are socially acceptable, at least in pilot trials. Such stoves can be produced from relatively low-cost materials and hold great promise of reducing wood consumption. This is especially so in areas where wood is scarce and its cost is high in proportion to the income of the poor. The methods for diffusing these improved stoves are, however, still untested on a large scale, and the social, cultural, and institutional obstacles to such diffusion remain to be understood and overcome.

3.27 There is also a good possibility that other cooking fuels derived from biomass may be technoeconomically viable. Such fuels include biogas, straw briquettes, and vegetable oil from oilseed crops. Improved technologies can also greatly increase the efficiency of charcoal manufacture. The comparative promise of such fuels, taking into account both economic and social factors, has not been adequately assessed.

3.28 Solar cookers have hitherto been notorious failures in numerous trials, largely because of the natural refusal of people to cook in the open in the heat of the day, but also for various other social and technical reasons. The need for a technological fix to the problem of the increasing cost of cooking fuel is so pressing that there is little alternative but to continue efforts to design a low-cost system, and to better understand the obstacles to its diffusion. To be successful, this must be compatible with the comfort of the cook, as compatible as possible with social and cultural norms, and possibly linked to a back-up wood stove. The assumption is that economic pressure will force the cook to consider an alternative technology with lower recurrent costs, however exotic it may be.

3.29 Biomass-based technologies for the production of heat for industrial processes and for generation of electricity are based on the direct combustion of one or another form of biomass in a boiler of compatible design. Such boilers are available, but there are no agreed performance standards to enable manufacturers to report the performance of their equipment according to an agreed format and test methodology. Solar collectors designed to produce high temperatures can also be used to supply process heat and generate electricity.

Table 2: TECHNOLOGIES FOR CONVERSION OF BIOMASS INTO USABLE FUELS

Conversion Process	Processed Fuel	Starting Material	Research Needs		Task for International Program	
			Major Gaps 1/	Who Should Fill These Gaps	Large-scale Technology	Small-scale Technology
Extraction	Fuel Oil	Oil seeds	Evaluation of existing small-scale equipment	LDC laboratory or consulting firm	None	A
Fermentation	Ethanol	Sugar, Starch	Design and adaptation for local conditions and energy efficiency	Industrial sector in developed and developing countries	B	A,B
Destructive Distillation	Methanol	Wood or other Cellulose	Reduction in costs through improved process	Industrial sector in developed countries	None	None
Carbonization	Charcoal	Wood	Adaptive research on small-scale plants	Private organizations and firms in LDCs with external collaboration	None	A,B
Digestion	Gas/biogas (methane)	Animal and agricultural Residues	Low-cost design and adaptation using local materials	Public and private laboratories. Private organizations, and firms in LDCs	None	A
Pyrolysis	Oil, char, producer gas	Urban Wastes, Agricultural Residues, Wood	Adaptation to local conditions.	LDC industrial sector	B	None
Briquetting	Briquettes	Agricultural Residues, Straw	Development and adaptation of small-scale machines	Public and private laboratories, private organizations, and firms in LDCs	B	A,B
Gasification	Producer Gas	Wood, Agricultural Residues	Development and adaptation of small-scale machines	Public and private laboratories, private organizations, and firms in LDCs	None	A,B

1/ See also right hand column.

A - Develop agreed evaluation methodology for users; encourage exchange of design and performance data among workers in different countries; review state-of-the-art.

B - Develop and promulgate standards by which manufacturers can report performance data, and criteria by which users can judge suitability to various applications.

October 30, 1980

Table 3: MAJOR TECHNOLOGIES FOR USE OF RENEWABLE ENERGY RESOURCES FOR THE PRODUCTION OF HEAT AND MECHANICAL AND ELECTRIC POWER

Form of Energy	Technology	Major Technological Gaps[1/]	Who Should Fill These Gaps	Task for International Program
Low Temperature Heat (below 100°C)	Solar Water Heating	Local adaptation and manufacture	LDC industrial sector	A
	Solar Crop Drying	Calculation of optimum design, local adaptation and manufacture	LDC laboratories and industrial sector	A, B
Medium Temperature Heat (100-300°C) (Cooking)	Cooking Stoves	Local adaptation and fabrication	LDC laboratories, extension and artisan training, services private organizations	A
	Solar Cookers	Low cost heat storage and transmission	Laboratories and private organizations in developed and developing countries	A, D
(Process Heat)	Solar Ponds	Research on unlimited ponds: Control of wind effects Local adaptation and fabrication	LDC industrial sector and public sector laboratories	A, C
	Solar Collectors Flat-Plate Focussing	Local adaptation and fabrication	LDC industrial sector	B
High Temperature Heat (above 300°C)	Combustion of Biomass in boilers	None	-	B
Mechanical Shaft Power (stationary)	Commercial Windpumpers	Local manufacture	LDC industrial sector	A, B
	Sail Windmills	Reliable performance data: comparative evaluation and improvement of traditional designs	Laboratories and private organizations in developed and developing countries	A, C
(Mobile)	External Combustion Engines Rankine Cycle Sterling Cycle	Design and adaptation to local resources	LDC industrial sector	A, B
	Internal Combustion Engines			
	Pedal Power	Development and assessment of alternative designs	National laboratories, rural extension bodies	D
	Draft Animal Power			D
Electricity Generation	Small Hydro	Local adaptation and manufacture	LDC industrial sector and government agencies	A, B
	Wind Generators	Develop and test equipment	Developed country industrial sector.	A, B*
	Photovoltaic	Cost reduction in cells and "balance of system" costs: encouragement of applications where market incentives are limited	Developed country industrial sector: international demonstration and generation of performance data	B, C**

1/ See also right hand column.

A - Develop agreed methodology for evaluation by users: encourage exchange of design and performance data among workers in different countries: review state-of-the-art.

B - Develop and promulgate standards by which manufacturers can report performance data, including suitability criteria for most important implications.

C - Generate performance data by internationally managed or coordinated field demonstrations.

D - Rekindle interest in hitherto neglected technology e.g., by educational materials, conferences, demonstrations, small research grants.

* When technology nears techno-economic feasibility.

** For specific applications for which private investment is likely to be inadequate.

3.30 Of the technologies for the production of stationary mechanical shaft power from renewable energy resources, that for commercial windmills mechanically linked to a water pump (wind pumpers), is well known and proven. It requires only application in sites where it is technoeconomically feasible. Again, there is no standardized format for testing and reporting performance data.

3.31 A promising "non-commercial" technology for pumping of water by wind energy is that based on the traditional small-scale sail windmill. This has been used for centuries in regions of Crete, Thailand and the Yucatan (Mexico) with reliable, steady, and low-speed winds. Such windmills have been successfully installed by private voluntary organizations in Tanzania. They are technically inefficient but are very cheap to construct, and can be fabricated and repaired in traditional local workshops. On the other hand, there is an almost complete absence of reliable cost and performance data.

3.32 Many systems are actually or potentially available for the provision of stationary mechanical shaft power from fuels derived from biomass through either external or internal combustion engines. External combustion engines, operating by the Stirling or Rankine cycles, may be powered by high or medium temperature heat from any fuel, and are respectively suited to small and large-scale applications. Stirling engines are claimed to have the particular promise of cheap local production in developing countries for water pumping applications. However, their performance in developing countries has not been tested.

3.33 Internal combustion engines, which are usable for stationary or mobile mechanical shaft power, produce the form of energy where fuels derived from biomass can be most directly and conveniently substituted for fossil fuels. Diesel engines can be fuelled by gas derived from biomass; by vegetable oils; or by other exotic vegetable products, such as the sap of the copaiba tree or the refined latex of certain species of Euphorbia (milkweed). Similarly, gasoline engines can be powered by liquid or gaseous fuels derived from biomass. In this relatively new application of renewable energy technology, there again do not exist agreed standards, i.e., test methodologies by which manufacturers of engines adapted to running on ethanol and other biomass-derived fuels can report performance data.

3.34 The draft animal is a major source of stationary or mobile mechanical shaft power from renewable sources of energy in many developing countries. Despite its dominance in the agricultural economies of many developing countries, the role of the draft animal is for the most part unstudied. No country has an integrated policy program or institutional framework for dealing with the technology of draft animal power, including genetics, feed, veterinary medicine, harnesses, tools, and vehicles.

3.35 Human pedal power is the most elementary technology for the production of mobile or stationary mechanical shaft power energy. The humble bicycle pedal and sprocket is an extremely efficient device for the exploitation of human musclepower, as is shown by the recent successful flight of a pedal-powered airplane over the English Channel. Bicycles are used all over the world, but especially in Asia, for the transport of peoples and goods. Low-cost, ergonomically sound designs exist for low-lift pumping, threshing, and grinding by pedal power. Pedalling is drudgery. Still, the widespread use of equally exhausting, yet less efficient technologies, such as the use of handpumps for irrigation in South Asia, shows that a low-cost pedal power technology would find a market and could contribute to productivity. As things now stand, a design available in one part of the world may be completely unknown in another, and reliable performance data are virtually nonexistent.

3.36 Electricity may be generated from large- and small-scale hydro installations, from the combustion of biomass in a boiler, from internal or external combustion engines fed by biomass, or from a system combining thermal energy from a solar pond or a solar thermal power plant (using focussing collectors) with a prime mover. Electricity may also be generated by photovoltaic cells and by small- and large-scale wind electric conversion systems ("wind generators"). These installations may stand alone, may be interconnected with a grid, or may be combined as a hybrid system in which one source of energy complements or backstops another.

3.37 Small-scale wind electric conversion systems are already cost-effective for remote windy areas. Similarly, small-scale hydro power involves well-known and proven technology. However, widespread application in developing countries will require the development of cost-effective approaches to site identification and evaluation, and the design of equipment adopted to local conditions and to low cost manufacture by local industries. Agreed standards for testing and reporting performance data would greatly facilitate the application of both technologies. A possible application of small-scale generation of electricity by wind or hydropower of wide potential interest is the small-scale manufacture of fertilizer in remote areas by the electric arc process. This has been demonstrated recently at the laboratory scale.

3.38 Large-scale (more than 200 kw) wind electric conversion systems based on modern materials and aerodynamic principles are undergoing rapid research and development in technologically advanced countries. Partisans of this technology predict that within about five years it will be competitive with other technologies for generating power for electric grids under favorable wind conditions in developed countries, depending on the rate of increase in fossil fuel prices. The technology would be available to developing countries through commercial channels.

3.39 Photovoltaic cells, which convert sunlight directly into electricity, provide the outstanding example of an advanced renewable energy technology that is likely to be transferrable to developing country conditions without significant adaptation. These cells are competitive today only for applications requiring a small quantity of electricity remote from a grid. Manufacturers in technologically advanced countries — and the governments who support them — predict a rapid decrease in the cost of the cells. There still remains, however, the cost of the "balance of the system." This includes the mechanical supports to the cells, electronic equipment to "condition" the power and make it compatible with the proposed application and, in many instances, for energy storage capacity. The last named is a high priority subject for privately financed research in technologically advanced countries. The application of photovoltaic technology is being promoted by manufacturers based in developed countries. Numerous tests and demonstrations are taking place in developing countries, 1/ although often without adequate provision for the collection of performance data for comparative purposes, or for general evaluation or follow-up.

1/ The UNDP has financed and the World Bank is executing a comparative evaluation in three countries of photovoltaic irrigation pumps suitable for small farmers, along with limited tests of a solar thermal pump, and is considering extension of this project to additional countries in a second phase.

B. Recommendations

3.40 The following specific recommendations for international support for the development of renewable energy technologies fall into two clearly defined categories: one for agricultural technologies and one for technologies for the production of heat, mechanical and electrical energy.

3.41 Biomass production technology offers clear opportunities for a major advance in the state of the art through research. It is reasonable to expect a well-designed and executed research program to improve the productivity of well known species, such as sugarcane, cassava, sweet sorghum, and various fuelwood and leguminous trees, and to identify species that are potentially even more productive. This would benefit virtually all developing countries. Only one or two of these countries, however, could organize such an effort on their own. An international effort would make possible an efficient program which would benefit all developing countries. This program must first investigate improvements in technology for the production of biomass from well-researched species, such as sugarcane, cassava, and many species of trees.

3.42 In sugarcane production, there is a threefold need: to breed varieties specifically for their potential as biomass producers; to collect germplasm from border areas of China, India and Burma, the last area in the world with major resources of uncollected germplasm and an area from which wild varieties are in danger of disappearing; and to study regimes to maximize biomass yield through proliferation of woody material ("energy cane"). In the case of cassava, genetic materials need to be collected and soil conservation systems investigated to minimize soil depletion. Comparative yield evaluations need to be made for sweet sorghum, a crop little known outside the United States, to investigate its potential advantages over sugarcane, cassava or other fermentable crops under special ecological conditions.

3.43 Research on the growing of trees should be substantially expanded to include tests of promising provenances and of species not now grown artificially on a large scale, and of non-conventional planting and harvest regimes. A program should be established to test promising new species of trees, shrubs, rootcrops and grasses in a variety of sites, and to compare their potential as biomass producers with each other and with traditional producers such as oilseeds and sugarcane. 1/

3.44 It is also recommended that national programs of agricultural research dealing with small farmer agriculture, the multilateral and bilateral agencies that assist them, and the international agricultural research centers funded by CGIAR, devote increased attention to the role of trees in small farmer agriculture, both as sources of fuelwood and, in the important case of leguminous trees, of fertilizer. Further staff work and consultations with the research community, as well as with such organizations as FAO and the International Center for Research in Agro-Forestry, are needed before detailed proposals in this area can be elaborated.

3.45 The bulk of the technologies for the use of renewable energy in developing countries to produce heat, mechanical and electrical energy, are embodied in processes and equipment based on well-known principles that need only be adapted to specific circumstances in developing countries. However, the application of some technologies depends on scientific progress that is most likely to be achieved by research programs in the industrialized countries.

1/ Yates has recommended the following species for comparative tests: cassava (rainfall more than 1,000 mm, or with irrigation), buffalo gourd, euphoria, castor, safflower, sesame, sunflower, saltbush, spartina (the last two especially when saline irrigation is possible); neem, jojoba, carob (Mediterranean style climates), and tamarind (dry tropical climates).

3.46 In the case of those technologies which require only adaptation to the circumstances of developing countries, the major task facing the international community is to support national capabilities and programs of research, development, commercialization and diffusion. This support would include efforts to adapt smaller-scale technologies to local needs by private organizations devoted to community development or to "appropriate technology."

3.47 In the case of technologies that depend on research and development in developed countries, there is a critical need for an international effort to assess the usefulness, impact, and future development prospects of technological advances being made around the world. The primary objective would be to make developing countries better equipped to choose, adapt and create technology to meet their own needs. There is also a need to promote in industrialized and more advanced developing countries the development and commercialization of new or improved technologies for use in developing countries, and to encourage commercial arrangements to facilitate production of the relevant equipment in developing countries. Such arrangements will frequently involve relatively small firms which would not ordinarily seek foreign partners.

3.48 On the other hand, considerable practical difficulties can be foreseen in the direct funding or execution of international industrial research and development that is independent of national programs in these areas. To be effective such international research would have to include not only the design of systems and the design and testing of conceptual prototypes, but also close collaboration with potential manufacturers in developing manufacturing prototypes and involvement in the commercialization of the product. These programs require close working relations with the productive sector, and this is difficult even for a publicly owned institute at the national, let alone the international level.

3.49 In general, the critical need of decisionmakers in the developing countries is to be able to assess the technical and economic aspects of processes and equipment. They can do so through information on the present state of, and likely future developments in, technology that is sufficiently evaluated to form the basis for strategy and decisionmaking. For example, planners need to know the best present assessment of whether diesel fuel could in the future be most economically derived from wood, from oilseeds, or from animal and agricultural residues. They also need to know how fuel from such sources is likely to compare in price and quality to that derived from conventional or novel fossil fuels. In addition, officials and entrepreneurs in developing countries need reliable performance data on alternative pieces of equipment; evaluated experience with the technological, institutional, and social aspects of different applications of renewable energy technology; and disinterested assessment of alternative applications of renewable energy technology to high priority needs of the developing world, preferably in comparison with traditional technology or modern technology using fossil fuels.

3.50 Criteria by which to judge the suitability of alternative technologies for various applications and conditions have not, however, been developed. Moreover, in many cases, the data required do not exist. There have rarely been disinterested comparisons of alternative systems for the many applications typical of the developing world. Even the methodologies for such comparative evaluations are still under development. The present sources of data and evaluations for many technologies are the manufacturers of equipment, who are mostly found in developed countries, who generally have no agreed standards for reporting performance data, who naturally convey an optimistic view, and who do not adequately consider social and institutional problems. Tables 2 and 3 summarize briefly the work of a proposed new international program to meet this need for technological assessment.

3.51 For many technologies, such as large-scale pyrolysis and briquetting, which are likely to be embodied in equipment manufactured in the developed countries and in the modern sector of more industrially advanced developing countries, the most economical approach is to develop and promulgate, in cooperation with manufacturers, users, and (as appropriate) private community development organizations, internationally agreed standards by which manufacturers would report performance data. (Such technologies are designated A in the "task for international program" column of Tables 2 and 3.)

3.52 For technologies that are likely to be embodied in equipment suited to small-scale manufacture in developing countries, or to artisanal or self-help construction at the village or community level, the major need is for agreed methodologies by which the user can evaluate the performance of the equipment and the broader aspects of his experience with the technology. Such methodologies can be used as a framework within which to facilitate the exchange of designs and performance data and the issuance of periodic reviews of the state of the art. (Such technologies are designated B in Tables 2 and 3.)

3.53 For certain technologies (designated C and applied to technologies in Table 3 only), there exist neither reliable performance data nor realistic prospects for obtaining any from existing or prospective national or international programs. Such technologies include solar ponds, sail windmills, and biogas. These technologies are nevertheless promising. The promise is sufficient to warrant funding and management of international comparative demonstrations in several developing countries for the purpose of generating performance data. We have not recommended such programs for biomass conversion technologies on the grounds that such technologies are better suited to exchange of information among national programs in accordance with agreed methodologies and reporting format.

3.54 In the case of a few technologies (designated D and applied to technologies in Table 3 only), world interest has lagged to such a degree that there is a need for an international effort simply to revive professional interest. This can be done through seminars, publications, travel, demonstrations, and small research grants. Such technologies include draft animal power and pedal power. Solar cooker technology is also in need of revival because well-publicized failures have discouraged inventors from attempting to solve this critical problem in a manner satisfying both technical and social constraints.

3.55 Finally, there is a need for a limited amount of genuinely international research on a number of special topics, for example the optimization of solar crop dryers; the development of a continuous biogas digestor suited to dry, straw-rich fermentation mixtures; and the development of simple, practical microcomputer programs to estimate the incoming solar radiation in the field.

3.56 This tentative work program is based, not only on the relative priority assigned to each technology, but also on the degree of interest now being shown by the international research community and the type of international assessment needed by decision makers and researchers in developing countries. It should be checked against expert opinion in different parts of the world. More detailed assessments should also be made of the potential contribution of the various technologies, taking into account likely future developments and the likely cost of the work proposed.

IV. CONCLUSIONS

A. Summary of Recommendations

4.01 The recommendations in this report reflect its objectives: to examine the needs not only for research on renewable energy suited to the conditions of developing countries, but also for building technological capacity in these countries for the use of renewable energy. It concludes that the countries involved would derive major benefits from increased investment in both these areas. A major impact on energy use in developing countries could result from a broad range of renewable energy technologies and applications — improved cooking stoves, biomass production for combustion or fermentation, biogas, windmills, gasification of wood or agricultural wastes. But major benefits can only accrue if the countries develop the capacity to mobilize these technologies to meet their own needs.

4.02 The report accordingly proposes a global strategy for research and assessment of renewable energy technology, and for the development of capacity within developing countries to mobilize that technology. It recommends that existing bilateral and multilateral assistance to national programs for the application of renewable energy technology be expanded and reoriented towards increased emphasis on the strengthening of local technological capacity.

4.03 The report concludes that a major international initiative is urgently required to assist the developing countries to develop their own capacity to mobilize renewable energy technology, to speed the development of improved technologies suited to their needs, and to facilitate the transfer of technology. New international programs are needed to:

(a) assist developing countries to diagnose needs for building local scientific and technical capacity for renewable energy developments;

(b) improve technologies for producing biomass from familiar crops (sugarcane, cassava, sweet sorghum) and investigate the potential of familiar and novel species, including trees, shrubs, grasses, and oilseeds, for biomass production on nonagricultural land under different ecological conditions; and

(c) develop reliable data on the performance of renewable energy technologies for the production of heat and mechanical and electrical power, evaluate experience in different countries with such technology, and make global assessments of future technological developments and their implications for renewable energy use in developing countries.

B. Institutional Arrangements

4.04 The proposed operating arrangements for each of the three international programs recommended in this report are summarized below. The bulk of the programs and activities described above would be carried out by existing institutions in the developing and industrialized countries. Central administrative staffs would be relatively small, and further consideration would be needed to decide whether they should be combined or maintained as separate units. We have not in this paper considered arrangements for governance and funding, except to note the need for adequate and secure finance, high professional standards on the part of the staff, and freedom from excessive political interference.

4.05 Diagnostic Assistance Regarding Local Technological Capability. There appear to be two promising institutional approaches to the provision of diagnostic assistance. One is the establishment of an autonomous international institution analogous to the International Service to National Agricultural Research (ISNAR: see footnote to para 2.26); the second, a project funded by the UNDP or the UN Interim Fund for Science, Technology and Development, and executed by the World Bank and perhaps the regional development banks. There may be advantages to working within the framework of existing institutions in order to avoid or minimize uncertainties, delays and costs due to start-up.

4.06 Biomass Production. Trials should take place in existing breeding stations and agricultural laboratories, chiefly located in developing countries. A number of laboratories now specializing in forestry and sugarcane, national agricultural stations and the international agricultural institutes funded by CGIAR would all be competent to undertake such work. The trials would be funded and coordinated by a small central secretariat of about three professional plant scientists, backed by sufficient administrative capability to manage 20-30 simultaneous research contracts in different parts of the world. More details concerning the work program and organization of this research are found in the Yates report. This secretariat would need to collaborate closely with the FAO.

4.07 Technology Assessment. The organization of the recommended international programs of testing, evaluation, assessment, and research would have to be designed to accomplish three functions: (i) general oversight of the program, (ii) management of global programs on specific technologies and applications (e.g. solar pond field trials, collect and review performance data on wind generators), or cross-cutting subjects (e.g. evaluation methodology); (iii) execution of specific tasks (e.g. tests of solar ponds or wind generators at a particular location).

4.08 The general oversight would be carried out by a small central secretariat with responsibility for policy and program formulation for fund-raising, and, for overall technical and administrative oversight. It would be advised with respect to the development and updating of its policies and work programs by a technical advisory committee. This would be composed of internationally recognized experts in research, development, and application of renewable energy technology and its integration into overall development.

4.09 International programs on specific technologies and applications would be managed either by the central secretariat itself, or on its behalf by ad hoc "lead institutions" chosen to manage a particular program or work on a particular technology. These would be selected from developed or developing countries or international institutions which have been playing a leading role in the development of the technology in question and which would for this purpose set up distinct units for management of the international program.

4.10 The execution of specific research tasks would be carried out either in the lead institution (where one has been designated) or preferably on contract from it or from the central secretariat to existing institutions in developing countries. The central secretariat would itself carry out only those studies necessary for the development of overall policy and program.

4.11 Special provision in programs concerned with small-scale technologies should be made for the participation and support of private "appropriate technology" organizations. These organizations have made important contributions to renewable energy technology. They have been especially effective in addressing the needs of poor people, despite (or perhaps because of) their small size and unorthodox approach. An effort should be made to develop special flexible procedures consistent with the need of these groups for relatively small amounts of money for travel, newsletters, conferences, publications, testing and research.

4.12 More generally, the small inventor or researcher is a major source of innovation in many fields of renewable energy resource development. These researchers may be found in a laboratory, in an enterprise or in a private voluntary organization in a developed or a developing country. Even well-established investigators frequently find it difficult to raise relatively small sums of unrestricted money, which are critically important to their capacity to respond flexibly to new opportunities and to communicate and collaborate effectively with their colleagues. Such small grants require a special administrative style that is difficult to mesh with the requirements of large programs; it is recommended that mechanisms for small grants be set up to deal with such requests.

C. Next Steps

4.13 This paper has been proposed as a contribution to the worldwide discussion of renewable energy research in developing countries taking place in preparation for the United Nations Conference on New and Renewable Sources of Energy. In November 1980, the World Bank will convene an Ad Hoc Advisory Committee of distinguished experts to consider the subject. A revised report taking into account the Committee's comments and recommendations will be prepared thereafter.

MOD 13

Technical Change, Catching up and the Productivity Slowdown

by

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Abstract

This paper puts forward a number of speculative and less speculative views in relation to what has been called the 'productivity paradox'. i.e. the simultaneous existence of potentially 'revolutionary' new technologies, such as microelectronics, and low and falling productivity, growth.

Within such an economic climate, it is argued that the issue of 'technological unemployment' is relatively trivial, a more relevant question focussing more on the reasons why technical progress has had such a negligible effect on output and productivity growth in the more recent years.

One of the reasons for the productivity slowdown in most European countries and Japan, is linked to the end or near-end of catching up, following the large technological gap with the US after the Second World War. It is argued that following this process of 'convergence', a divergence process might well be set in motion on the basis of some sort of absolute technology advantage.

I

Technical Change and Employment in the 1970s: A productivity paradox?

Much of the 'popular' discussion around the employment displacement effects of technical change, in particular the debate around microelectronics[1], seems increasingly to get trapped into the paradox of low and falling productivity growth, which has been one of the major and most striking features of the mid-seventies, and early eigthies. If the technological change associated with modern electronics is indeed of the radical and basic nature indicated by most technologists, i.e. that it not only offers scope for new and improved products and/or increases in efficiency and cost reductions in the innovating industry, but throughout the economy at large, then surely the clearest indication of its overall impact, including its possible employment displacing effect,should be found in rapid increasing productivity levels throughout most of the sectors of the economy. Yet, as Table 1 suggests that has not been the case. Not only is the evidence clearly against it , a number of recent 'growth accounting' exercises, particularly in relation to the US[2], have indicated that for the 70's, as opposed to the 50's and 60's, there is actually <u>no</u> evidence of any effect of technical change on economic growth, and productivity growth in particular (Griliches,1980). On the contrary, in the case of Denison (1979b), the estimated growth contribution of 'Advances in knowledge and misc. determinants' (the residual) has even turned negative. For sure,this evidence relates only to the US, and one cannot just extrapolate these results to other European countries. Yet the fact that in most other OECD-countries productivity growth has slowed down[3]

1.see e.g. Jenkins and Sherman,1980.
2.for an overview,see Thomas,1980.
3.for an excellent analysis and overview see Boyer and Petit,1979, (EEC) and OECD,1980a(OECD-countries)

Table 1 : Productivity Growth in Industry in the 70's (EEC-9)

Year	Belgium	Denmark	Germany(FR)	France	Ireland	Italy	Luxemburg	Netherlands	UK
1971	4.2	6.2	2.1	4.7	3.8	-1.0	-3.6	3.9	3.3
1972	9.2	5.0	4.7	5.0	5.8	4.9	3.4	6.0	6.0
1973	9.4	2.7	5.7	4.4	5.9	8.5	7.3	9.2	7.0
1974	2.4	5.5	4.1	2.3	-0.4	3.7	2.0	4.3	0.0
1975	-1.4	7.1	0.7	1.7	-7.0	-9.4	-18.0	-2.4	-0.6
1976	13.0	7.5	9.2	8.6	10.6	12.4	7.6	12.0	6.8
1977	4.0	3.3	3.8	4.0	3.1	2.0	3.3	3.4	0.2
1978	5.8	3.1	1.8	4.0	4.5	2.8	10.8	3.6	1.7
1979	7.1	3.7	4.3	5.1	5.0	6.9	5.8	4.0	1.2
1980	3.3	1.9	1.2	2.7	-1.8	5.0	0.1	2.9	-4.2
1981*	3.0	1.5	2.4	1.8	6.9	-2.9	-4.4	4.1	2.6

Source: EEC-European Economy, March 1981.

* estimated.

leading to a breakdown of most 'short-run' (and medium term[1]) employment functions after 1973/74 (particularly in the case of Sweden[2] and the UK[3]), seems to indicate that one is confronted with a general decline in the underlying rate of productivity growth.

There are obviously a whole range of explanations for this slow down in productivity growth, ranging from the negative effects of anti-pollution measures and expenditures (Denison,1979a), the rise in the price of energy (stressed primarily in EEC,Maldague-Report, 1980, and OECD,1980c), to a slowdown in the formation of capital itself (see e.g. Haltmaier,1980). In relation to technology however, the explanations generally advanced are not so numerous : reduction in R&D effort (OECD,1980d), decline in the productivity of the scientific and technological system and possible increases in the lag in the application of knowledge because of the slow down in investment. None of these fits however particularly well with the 'stylised facts' about the microelectronic revolution and the predicted dramatic increase in productivity, product innovation and profitable investment opportunities. A recent, and in my view rather plausible explanation has been advanced by Lamberton,Macdonald and Mandeville (1980), in terms of an inherent inefficient use of electronics technology, primarily information technology. It is actually best described by what they 'christened' the 'xerox effect', and undoubtedly something academics will be quite willing to believe : the enormous capacity of new information technologies to generate information for internal use, which might lead to too much information with less time left for decision-making

1. as e.g. in the case of Verdoorn-relationships, see e.g. Clark,1979
2. see e.g. OECD,1980b,pp42-51 and Appendix 1,and Carlsson,1980.
3. for an overview see Dean,1980.

and an ensuing decline in efficiency. According to Lamberton and his colleagues the main reason for this tendency towards inefficiency is linked with the firm's ignorance of the cost of information :

> "New information technology is adopted by the organisation to perform specific tasks. The nature of electronics technology means that a machine can often do more than was originally anticipated. Used on a production line, the machine can control the manufacture of not only square pegs, but round ones and triangular pegs too. If there is a perceived market for only square pegs, only square pegs will be manufactured. But information production is very different from peg production; the good is intangible, infinitely variable, and its characteristics and value can generally be assessed only after production. There is no way for the organisation to predetermine precisely what will be useful information and what will be useless. Even a retrospective assessment is likely to be difficult. Consequently, the inexpensive electronics hardware of modern information technology is used to full capacity to produce information indiscriminately. We do not know what effect this has on the efficiency of the organisation but Leibenstein's X-inefficiency concept may be pertinent;profligate use of information may be a major cause of inefficiency engendered by an activity internal to the firm."(Lamberton,Macdonald and Mandeville,1980,p.13)

There is however also little doubt that the slow down in productivity growth is directly linked to the very low and sometimes negative output growth of the last eight years. Excess capacity, underutilisation of capital with firms having to forgo their crucial economies of scale, hoarding of labour,etc.are all factors which might have had a significant influence on productivity growth, in terms of the short-term cyclical relation between output and productivity growth (see e.g. Okun's law), as well as in terms of the long-term relationship (OECD,1980a).

It is of course the present output crisis, which obscures so much the technical change-employment debate. Most of the latter[1], limited here to the European debate,developed within the early 70's, when a clear pattern of 'jobless' growth (Freeman,1977) started to emerge in the industrial sectors of most European countries. The evolution of output and employment can be most easily represented in graphical form. Figure 1 is an updated presentation of Soete(1978), where industrial employment and output for the nine EEC-countries are given for each year since 1950. As the figure illustrates,up to 1965 output growth was always accompagnied by employment growth, whereas form 1965 onwards a clear pattern of jobless growth started to emerge with continuous negative growth rates in industrial employment since 1973. For the latter period however, output itself started to slow down, with actual negative growth rates in 1975 and 1980. For this period and in particular the most recent years, it is difficult to say much about an underlying trend towards further rationalization and technical change job-displacement. For the post 1979 period it is indeed difficult to separate the business cyclical, recessional employment effects of the fall in output growth, from the long term 'structural' employment displacement effects of technical change. The fall in productivity growth mentioned earlier, suggests however, that the latter has only had a minor effect on the present (79-8?) employment crisis. The most recent unemployment figures seem to give further support for this view. In Table 2, unemployment rates for the years 1929-1935 and 1976-1981 (first three months) are presented. The figures for 1980 and 1981, indicate in general a sharp increase in the rate of unemployment, the exceptions being

1. We do not refer to the debates which developed in the late 20's early 30's, nor to the US debate of the early 60's in relation to automation. It is interesting however to read back these debates,particularly the employment displacement predictions (OECD, 1965,p.21).

FIG.I : Industrial Output and Employment in the EEC-9, 1950 to 1980 (1962=100).

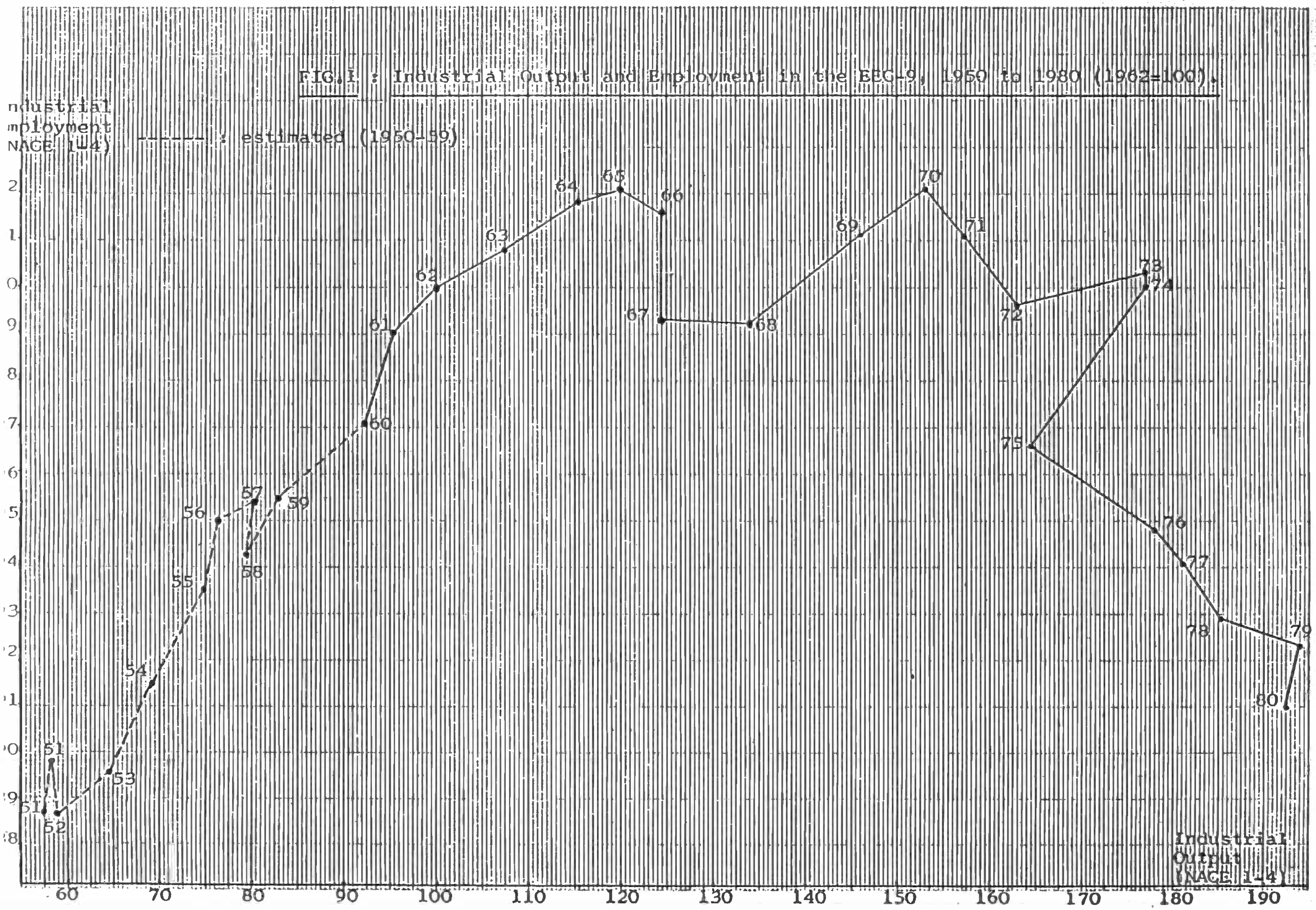

Table 2: Levels of Unemployment 1929-35 and 1976-81[a,b]

Countries	1929	1930	1931	1932	1933	1934	1935	1976	1977	1978	1979	1980	1981
Belgium	0.8	2.2	6.8	11.9	10.6	11.8	11.1	6.8	7.8	8.4	8.7	9.4	10.6
Denmark	8.0	7.0	9.0	16.0	14,5	11.0	10.0	4.7	5.8	6.5	5.3	6.2	8.0
Germany[c]	5.9	9.5	13.9	17.2	14.8	8.3	6.5	4.1	4.0	3.9	3.4	3.4	4.1
France	1.2	na	2.2	na	na	na	na	4.3	4.8	5.2	6.0	6.4	7.1
Ireland	na	na	na	na	na	na	na	9.4	9.2	8.4	7.5	8.3	10.0
Italy	1.7	2.5	4.3	5.8	5.9	5.6	na	5.6	6.4	7.1	7.5	8.0	8.3
Netherlands	1.7	2.3	4.3	8.3	9.7	9.8	11.2	4.3	4.1	4.1	4.1	4.8	6.3
United Kingdom	7.2	11.1	14.8	15.3	13.9	11.7	10.8	5.3	5.7	5.7	5.3	6.9	9.4
U.S.A.	3.1	8.7	15.2	22.3	20.5	15.9	14.2	7.7	7.0	6.0	5.8	7.1	7.2

Source: 1929-1935 Maddison,A.(1980),"Western Economic Performance in the 1970s:A Perspective and Assessment",Banco Nazionale del Lavoro Quaterly Review,no.134 September,pp.247-290.

1976-1981 EEC-European Economy,March 1981; and EEC-Short term indicators April 1981.

a : 1929-1935 as a % of total labour force ; 1976-1981 as a % of civilian labour force.

b : 1981 first three months only.

c : the Federal Republic for the period 1976-1981.

Germany (FR) and Japan, which gives further weight to the view that the present high unemployment rates are in first instance related to the recessional output growth tendencies, resulting from oil shocks or anti-inflationary government policies. 'En passant', it is worth noting that for a number of countries the unemployment levels for 1980 and 1981 are coming rather near to the 1930's level. Combined with the very low output growth for 1979/80 and the predicted ones for 1981 and even 1982, the present 'recession' seems to have more and more 'depressional' characteristics.

To conclude this first brief section, let me come back to the earlier mentioned 'microelectronic job-threat/falling-productivity growth' paradox. It seems as if the question as to the possible impact of new technologies on employment is, within the present economic climate rather trivial. If only 'new' technologies could stimulate and induce the system to higher growth levels seems somehow a far more relevant question ; if employment displacement were to occur during the process, couldn't it be solved rather easily ? As Samuel Brittan, Britain's leading 'economic commentator' puts it : "The micro-chip revolution, as popularly presented, presupposes a revolutionary increase in productivity. Let us suppose that it enables today's output to be produced by half the population. Is it likely that the economy will work so badly that half the working population, i.e. about 12m. people, will be unemployed; or so irrational that average working hours will be cut by half even when people still want more take-home pay?" (S.Brittan,1979,p.27). While, judging from the present-day working of the economy (and in particular the British one), one might well be tempted to answer Brittan's questions affirmatively, it seems nonetheless reasonable to assume that, confronted with

1.To give more credit to the labour saving technical change argumentation, we assume that output growth is in some way supply con-

the massive increase in wealth ; either in terms of 'pure' labour time saving, or some output growth and labour time saving, resulting from the use of the 'new' technology, labour displacement could be dealt with effectively through a more even distribution of available labour time (for a full employment policy proposal along these lines, see Soete,1980a).
In some way, and maybe underlying the slowdown in productivity growth, the various measures taken in some countries, in relation to early retirement, shorter working week, increased holidays,etc. are already first indications of such a policy. Once all the gains in labour time saving, resulting from technological change completely shared, the only problem would be what to do and how to organise leisure[1].

With the exception of 'work-alcoholics' (maybe they should be given jobs in academic research institutes), life would be paradisiac for everybody. A 'Brave New World' with only alpha's and all the rest machines.

1. See amongst other the increasing amount of sociological work on leisure (Gershuny,197

II

International Competition and 'Catching Up'

The main reason why such a 'paradisiac' world belongs still and will probably belong for a very long time to science fiction, is related to the fact that one cannot discuss the technical change-employment issue and especially its policy conclusions within a purely closed economy situation. The introduction of international competition alters the picture abruptly[1]. Were a country to opt for a specific employment strategy aimed at distributing the productivity gains of new technologies in terms of increasing employment (in many ways the picture which emerges out of the output, employment and productivity growth in Sweden during the period 1974-1977 suggests such a policy, see e.g. OECD,1980b), its effect on the country's international competitiveness would be felt rather quickly and it would practically be forced to reduce its relative labour costs (see e.g. the Swedish devaluation in 1977).

The major factor underlying the importance of international competition within the technical change-employment debate is of course the international diffusion of technology. For sure, technology acquires only commercial value through 'appropriation' (Cooper and Hoffman,1978 for a clear and succinct argumentation). Its international diffusion is thus neither free and costless, nor immediate. Technological 'assets' represent monopoly power, and it has been shown that a large proportion of the OECD's manufactured exports is dominated by these technological assets (Hatzichronouglou,1980, Soete,1980b,1981). Yet there is little doubt that technologiacl appropriation is highly imperfect at the international level. Today, new technology gets diffused rather rapidly, and allows generally speaking the other developed 'imitating' countries 'to catch up'.

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1. For a formal theoretical argumentation, in terms of the adoption and non-adoption of labour-saving technology by one country vis-a-vis the rest of the world, see Dosi,1979.

The international diffusion of technology has been a crucial factor in the development and economic growth of most developed countries. Particularly when a clear technological leader can be identified (e.g. the US since the 2nd World War), there seems to be scope for a process of rapid 'catching-up' growth (Cornwall,1976, see also Singer and Reynolds,1975),where the mere existence of a technological gap may provide a sufficient incentive for rapid economic growth. According to Gomulka (1971), one can actually consider two sorts of diffusion mechanisms : the first, the free exchange of scientific and technical information follows directly from the technological gap ("technological gap will be thought of as a pump of diffusion" p.11), the second consists of the actual import of technology and its diffusion in the country. It is in first instance, the latter which will be most effective for successful industrialisation. Japan's success in following such a strategy is well-known : in 1950 it imported technology for less than $ 3 million, in 1963 for nearly $ 150 million, and in 1979 for more than $ 2800 million. At the same time its research expenditures rose from $ 129 million in 1953 to $ 1060 million in 1964 and $ 14200 million in 1977/78. It is the gradual shift of its 'endogeneous' technological effort from an auxiliary role to the import of technology, to autonomous technological development, which seems to be the crucial characteristic of Japan's emergence as a technological leader. Yet even in this situation it is still heavily relying on foreign technology,and its balance of technological payments is negative and still rising (see Table 4). Yet as indicated in Table 5, the balance between the receipts for technology exports and the payments for technology imports for <u>new</u> contracts as opposed to continued programs has turned positive since 1972 (a ratio of more than 1 in Table 5,see Vickery,1980).

Table 1
Balance of Payments : Other Private Services : Receipts and Payments for patents, licenses and similar fees

(million US $)

	1970	1971	1972	1973	1974	1975	1976	1977	1978
Argentina: Royalties									
Credit	9	5	5	10	11	18	23	14	
Debit	70	80	55	82	101	67	39	54	
Austria : Licences, patents and copyrights									
Credit		8	8	9	14	13	20	26	29
Debit		33	41	47	70	84	87	104	119
China (Republic) : Copyrights and patent royalties									
Debit	4	10	11	37	45	35	37	42	
Colombia : Copyrights and patent royalties									
Credit		3	2	2	2	2	2		
Debit		1	7	8	8	5	8	7	
Costa Rica : Patent royalties									
Debit		1.7	1.6	1.5	1.7	3.3	4	4	4
Germany : Licences and patents									
Credit		150	217	206	265	316	312	350	463
Debit		421	499	575	673	826	808	992	1176
Israel : Copyrights and patent royalties									
Debit		4	5	4	7	8	9	11	8
Italy : Patent royalties									
Credit		85	47	55	78	72	80	121	103
Debit		329	259	277	279	386	321	421	498
Jamaica : Royalties and similar income									
Debit		1.6	2.0	2.6	2.9	5	5	1.4	
Malta : Royalties and similar income									
Debit						0.5	0.5	1.4	
Netherlands : Royalties, licenses, copyrights, etc.									
Credit		105	104	129	160	185	209	224	277
Debit		116	153	174	237	280	356	358	446
Spain : Copyrights and patent royalties									
Debit		86	118	144	194	301	145	117	
Swaziland : Patent royalties									
Debit					0.6	0.6	0.6		
Trinidad and Tobago : Patents, royalties and similar fees									
Debit		2	0.7	1	3	3	2.5	2.7	3.1
Yugoslavia : Copyrights and patent royalties									
Debit	5	3	3	4	8	-			

Source : IMF, Balance of Payments Yearbook, December 1978, December 1979.
Values in SDR's converted to US$ at period average rate (sb).

Table 5

Japan : Receipts for technology exports as a proportion of payments for technology imports : New programs and continued programs
Fiscal years

N = new
C = continued

	1971		1972		1973		1974		1975		1976		1977	
	N	C	N	C	N	C	N	C	N	C	N	C	N	C
All industries	0.71	0.14	1.26	0.15	1.27	0.13	1.37	0.25	1.42	0.31	1.51	0.35	2.15	0.33
Manufacturing	0.56	0.12	1.35	0.14	1.21	0.11	1.44	0.25	1.16	0.29	1.28	0.35	1.89	0.32
Chemical products	0.87	0.19	4.81	0.22	4.82	0.23	3.45	0.56	1.51	0.70	11.7	0.67	3.63	0.55
Iron and steel	2.26	0.57	0.87	0.84	1.55	0.60	2.29	1.03	3.42	1.76	1.03	1.43	7.14	1.36
Non-elec.machinery	0.37	0.02	0.77	0.04	0.36	0.05	1.07	0.12	1.26	0.14	0.39	0.24	2.34	0.08
Electrical machinery	0.37	0.06	2.44	0.04	0.14	0.05	0.17	0.13	0.79	0.17	0.20	0.22	0.64	0.24
Transport	0.35	0.12	0.25	0.08	0.33	0.09	0.36	0.15	0.35	0.16	0.69	0.19	0.93	0.21

Source : Vickery,1980.

A similar pattern might well emerge out of the more recent evolution of technology imports in the case of South Korea, where both payments for imported technology have increased substantially over the 70's ($ 58 million in 1977), as well as research expenditure which was primarily aimed at enabling the economy to absorb quickly the foreign technology ($ 40 million in 1977).
There is also little doubt that the rapid growth in labour productivity which occurred in most West-European countries in the 50's and the 60's can be explained to a great extent in terms of this sort of technological gap induced 'catching-up' growth[1]. The technological gap between the US and Western Europe was at its deepest after the Second World War. As Agnus Maddison observes :

> "The USA developed its productivity lead initially in the period from the 1890's to 1913 at a time when its prospects were particularly bright because of its great natural resource advantages, huge internal market, and rapid population growth. This fostered higher rates of investment than in Europe and a faster growth of capital per employee. By 1913 the US productivity advantage over the UK - the old leader - was about a quarter. One cannot tell how wide this productivity gap would have become in "normal" circumstances. Eventually the forces making for US ascendancy would have faded, as indeed they now have. In the meantime, however, the productivity gap became very much bigger, mainly because of the two world wars-both of which stimulated the US economy and retarded the advance of the other countries. In 1950, there was an unnatural degree of dispersion between the USA and most of the other countries" (Maddison,1979,p.17) .

The importance of the international diffusion of technology and especially the import of foreign technology for economic growth, is

1.For an empirical verification of various growth patterns over the period 1890-1977, see Pavitt and Soete,1981.

also evident from the general technological balance of payment figures given in Table 4. With the exception of Switzerland, where the figures are very much influenced by tax advantages, the countries with a positive technological balance of payments ; the UK and the US, are also the countries which the lowest growth rates over the post-war period.

As the gap narrows however, and more and more countries draw nearer to the 'technological frontier', economic growth, in particular productivity growth, slows down and settles at the rate of advance of the technological frontier itself. While this phenomenon might explain for a good deal the slow down in productivity growth in a number of European countries and Japan, it doesn't explain the slowdown in the US, and it leaves the question open why the 'broadening' of technological leadership to Japan and a number of European countries (Germany (FR), Sweden, France, Switzerland), has not led to a quickening in the rate of advance of the technological frontier itself. One can think of various reasons why this does not seem to happen. It could well be that the productivity of science, and technology in particular, has slowed down (reduction in research expenditure on 'basic' science), and that we are now in a phase of rapid decreasing returns to existing science and technology, desperately waiting for a number of 'fundamental' scientific and technological breakthroughs.

A more plausible explanation sustains that with the narrowing of the technological gap and the 'catching-up' countries coming near to the technological frontier, there is a period of intense technological competition between the major 'contenders' for technological leadership, with a continuing increase in the autonomous research spending (as opposed to the preponderance of 'auxiliary-to-technology-import' research spending in the early catching-up phase), of the 'catching-up' countries, yet more and more duplicative research. In some way, the situation which arises is very similar to Arrow's(1962) competitive model, with less risk-taking research[1],but at the same time excessive directly-productive[2]research At the same time, the international diffusion of technology increases more rapidly, the various technological leaders competing against each other in domestic as well as foreign markets. The result is a further decline in the rate of return to inventive activity and innovation. Even the smaller countries, seeing their productivity growth more and more restrained by the rate of advance of the technological frontier, will increase further their 'autonomous' research effort, in order to achieve technoligical leadership in those sectors in which they have either developed some technology or export comparative advantage. A possible indication of such a trend can be found in Figure 2, which illustrates the evolution of R&D expenditures in the Business Enterprise Sector per capita over the period 1967-1977, in terms of the distance or proximity from the technological frontier (measured here as the ratio between each country's GDP per capita and the US GDP per capita level, see Pavitt and Soete,1981). Countries which have achieved GDP per capita levels above the US one in 1967 (Sweden and Switzerland) seem to have been forced to increase their R&D per capita levels dramatically with little or no effect on their own economic growth. With the exception of Canada, countries which have achieved GDP per capita levels above the US one in 1977 (Denmark,Norway and Canada), have also had to increase their R&D per capita levels significantly, though their growth performance

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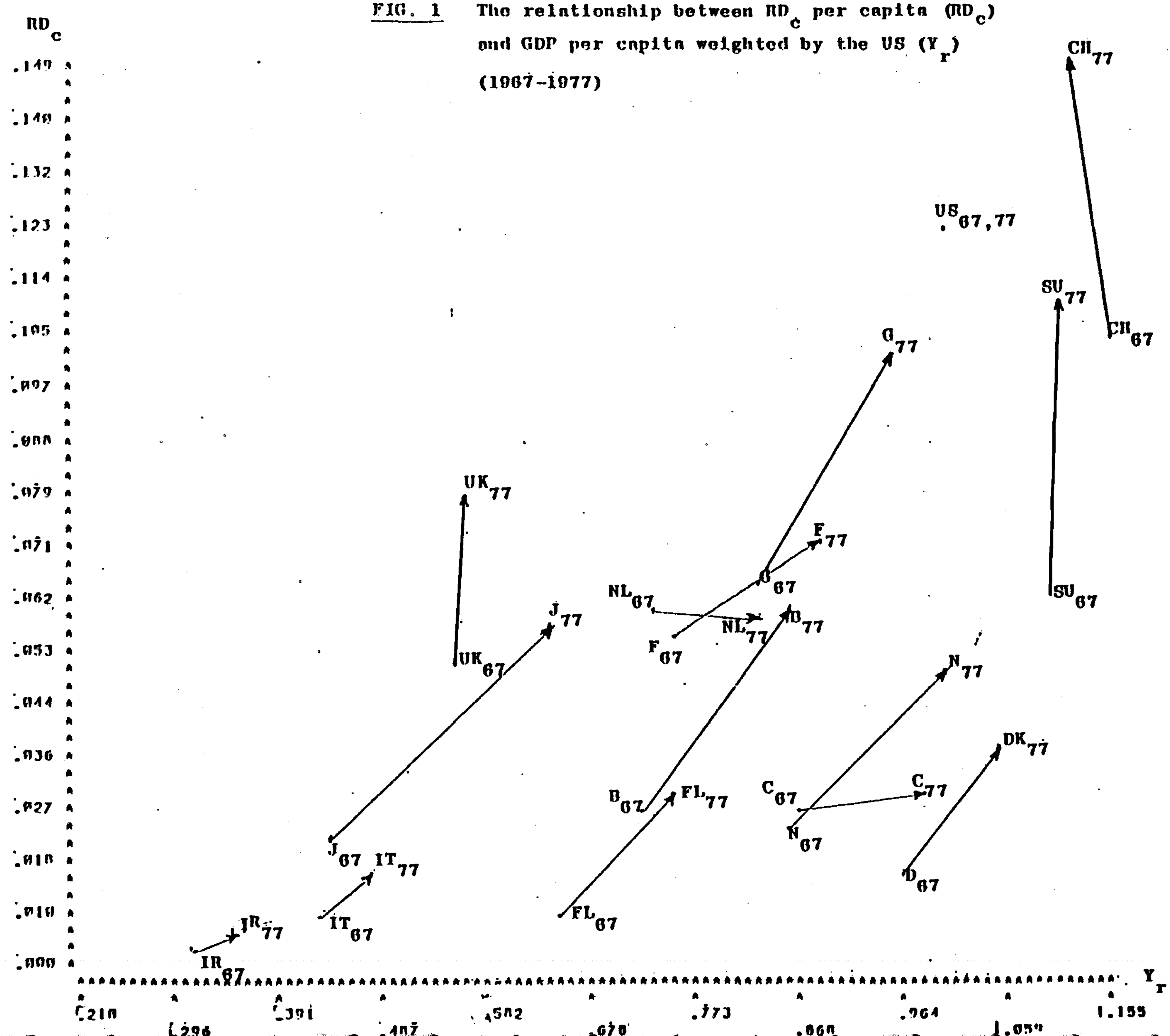
1. because of the fear of international diffusion.
2. perceived as 'directly-productive', in the long term however, there is less and less scope for this sort of research,decreasing returns setting in rather quickly and sharply.

FIG. 1 The relationship between RD_c per capita (RD_c) and GDP per capita weighted by the US (Y_r) (1967–1977)



was relatively good. The R&D per capita levels of these countries remains however relatively low, indicating that they have been relying heavily on technology imports in order to achieve that growth performance. Having drawn near to the 'technological frontier', one might expect that these countries will be forced to increase their R&D effort substantially, if they want to maintain their growth performance. For the other countries, with the clear UK exception, rapid 'catching-up' growth has been accompagnied by substantial increases in R&D per capita levels. Overall Figure 2 illustrates rather neatly, how countries have to increase their technological effort, when approaching the 'technological frontier' (the upward movement at the right hand side of the graph).

As mentioned before however, to the extent that the resulting increase in international technological competition reduces the rate of return to technology, most countries find themselves in the paradoxical situation of spending more on 'autonomous' research while the price for the import of technology has actually slowed down. As each country's 'technological assets' represent less and less monopoly power, so that the monopoly rent it can earn on its technology exports starts declining, it will finally be the degree of technological success, the relative labour costs, the availability of skills, and the extent to which government support is provided, which will determine which country(ies) will eventually emerge as the new technological leader(s). A process of 'divergence-growth' (Pavitt,1979,1980) will be set in motion, which will last till the newly created technological gap is sufficiently large to provide a sufficient incentive for the 'lost-out' countries to catch up.

III.

Conclusions

The sort of development just described is of course extremely speculative. The main trust of the argument is however that there is no reason why as e.g. in Gomulka's growth model, technological gap growth would only be a 'temporary' perturbating factor. Once its effect dissipated all countries would return to their natural population growth rates:"...the relative technological gap between the United Satess on the one side, and West Europe, the Soviet Union and Japan on the otheris gradually narrowing. All these countries are becoming one technologically unified and leading area. The unification will probably be completed as early as 1990 in the case of Japan and about 2010-2030 in the case of the USSR and West Europe. Then rapid growth will probably gradually disappear all over the area."(Gomulka,1971,p.58) However, precisely,the same conditions as existed in the case of the US in the period 1890-1913 (not to speak of both World Wars) and which allowed the technological gap to grow, might well exist for one or a number of countries in the near future. Convergence is indeed not a particular characteristic of human history.

But it is time to conclude. The relationship between technical change and employment is obviously far more complicated than generally assumed. Consequently, while there exist relatively simple policy solutions to the possible labour displacement effects of labour saving technical change, if one were to live,not only on an island, but also on a closed island , the whole picture becomes rather obscure once international competition is introduced, and it all seems to depend on these same old export and import price elasticities(see a.o. Boyer ,1979,p.8, and Dosi,1979). Yet, as we tried to argue in the first section, even if one were ready to ignore the rest of the world, there seems to be despite the much heralded microelectronic revolution, little scope for any 'sharing' of productivity growth, in terms of employment creation . The latter, and in some way paradoxically, has been slowing down since the mid-seventies , and particular in the present recession or depression seems to be at its lowest level ever. The relevant question seems therefore more to be how to increase productivity growth or alternatively what are the causes underlying the present productivity slowdown. In this paper we have focussed on international productivity growth explanations based on 'catching up' or 'technological gap' growth models. To the extent that they succeed well in explaining the productivity slow down in the 70's in the Western European countries and Japan, as a direct result from the closing down of the 'abnormal' technological gap with the US at the end of the 2nd World War, they are useful, and should be analysed far more carefully. Yet, to the extent that they overemphasize the 'mechanic', automatic aspects of past economic growth because of the mere existence of a technological gap, they are particularly unsuited to explain developing countries economic growth performance, and their overall predictive power, in terms of a convergence of all growth levels to population growth levels (how did technological gaps then develop?), is unfortunately limited[1].

1. Maybe slightly unfair, but it is indeed very tempting to quote Gomulka's prediction in relation to the UK productivity growth for the mid-seventies and eighties, resulting from the widening productivity gap between the UK on the one hand and the US, Western Europe and even Japan on the other :"The UK industry is at present under the increasing influence of the technologically and organizationally more innovative, and apparently already more advanced Western Europe and Japan. So, in principle, one may expect a further, though temporary rise in the UK's productivity growth rate from about 2.3 per cent in the 50's, 4 per cent in the years 61-74 to 5 per cent or so, characteristic now for Western Europe and Japan, followed by a decline to the US rate of about 3 per cent per annum" (Gomulka, 1979, p.191). For the actual figures of UK productivity growth, see Table 1.

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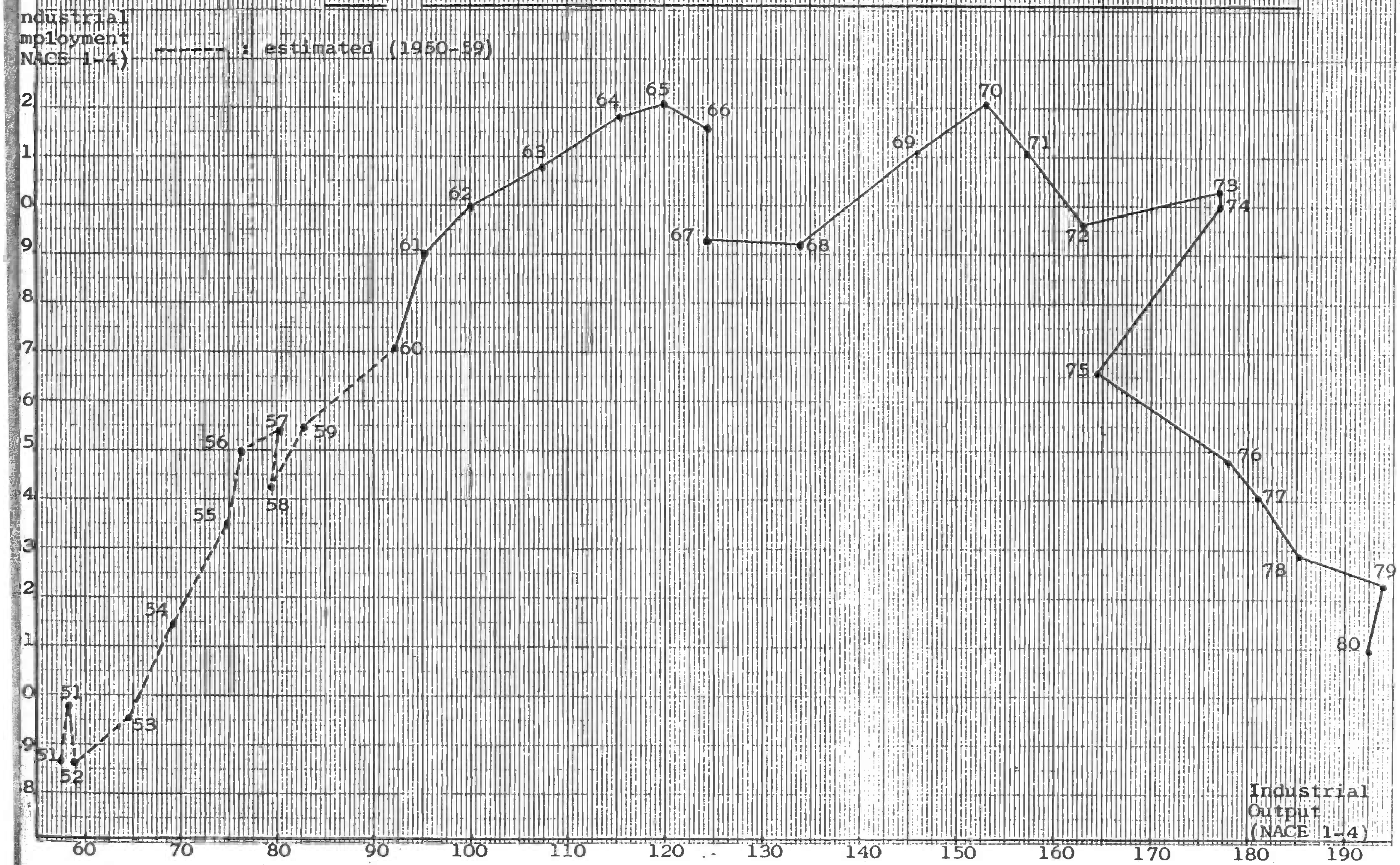
FIG.1 : Industrial Output and Employment in the EEC-9, 1950 to 1980 (1962=100).



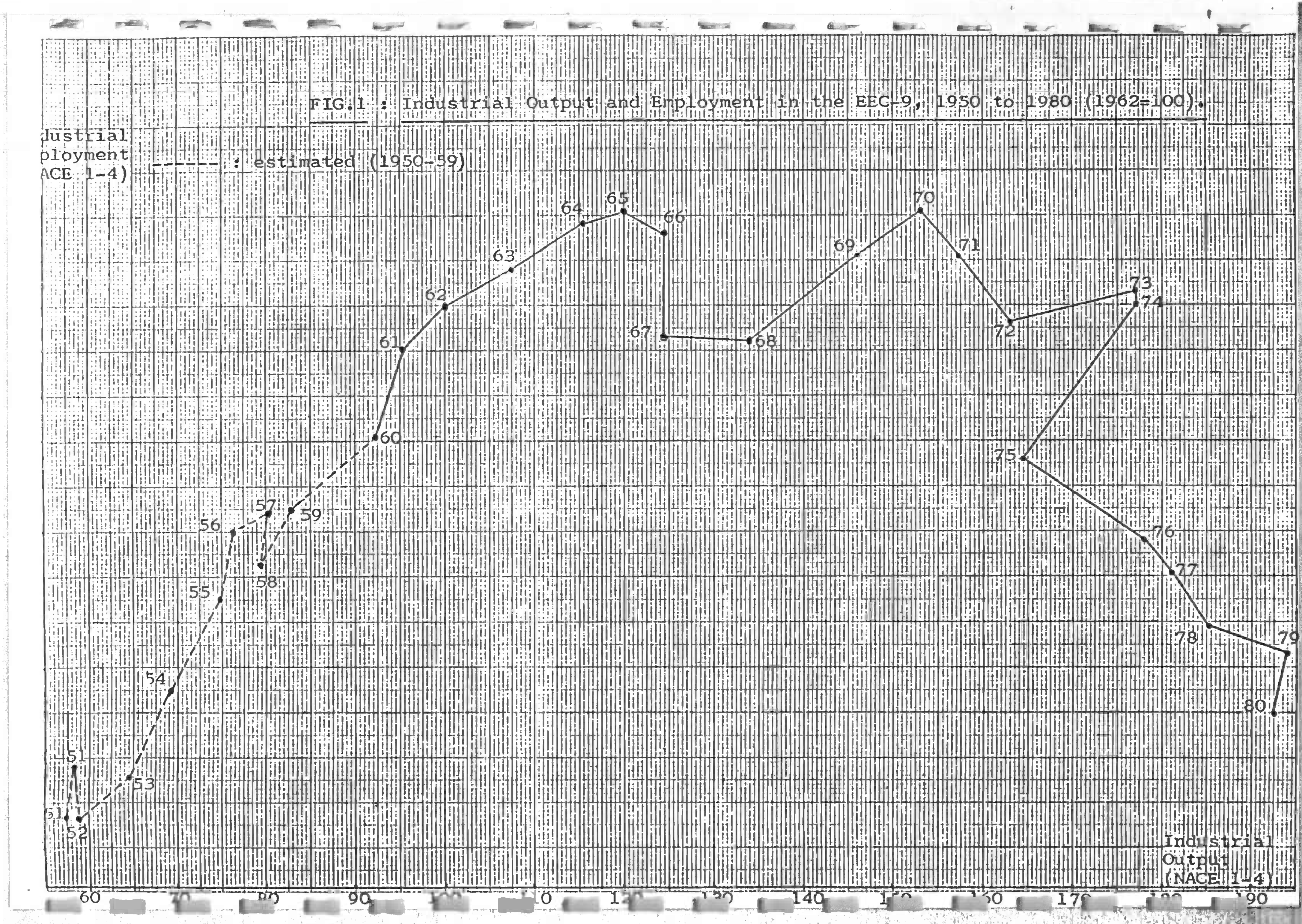


FIG.1 : Industrial Output and Employment in the EEC-9, 1950 to 1980 (1962=100).
Industrial Employment (NACE 1-4)
------ : estimated (1950-59)
Industrial Output (NACE 1-4)
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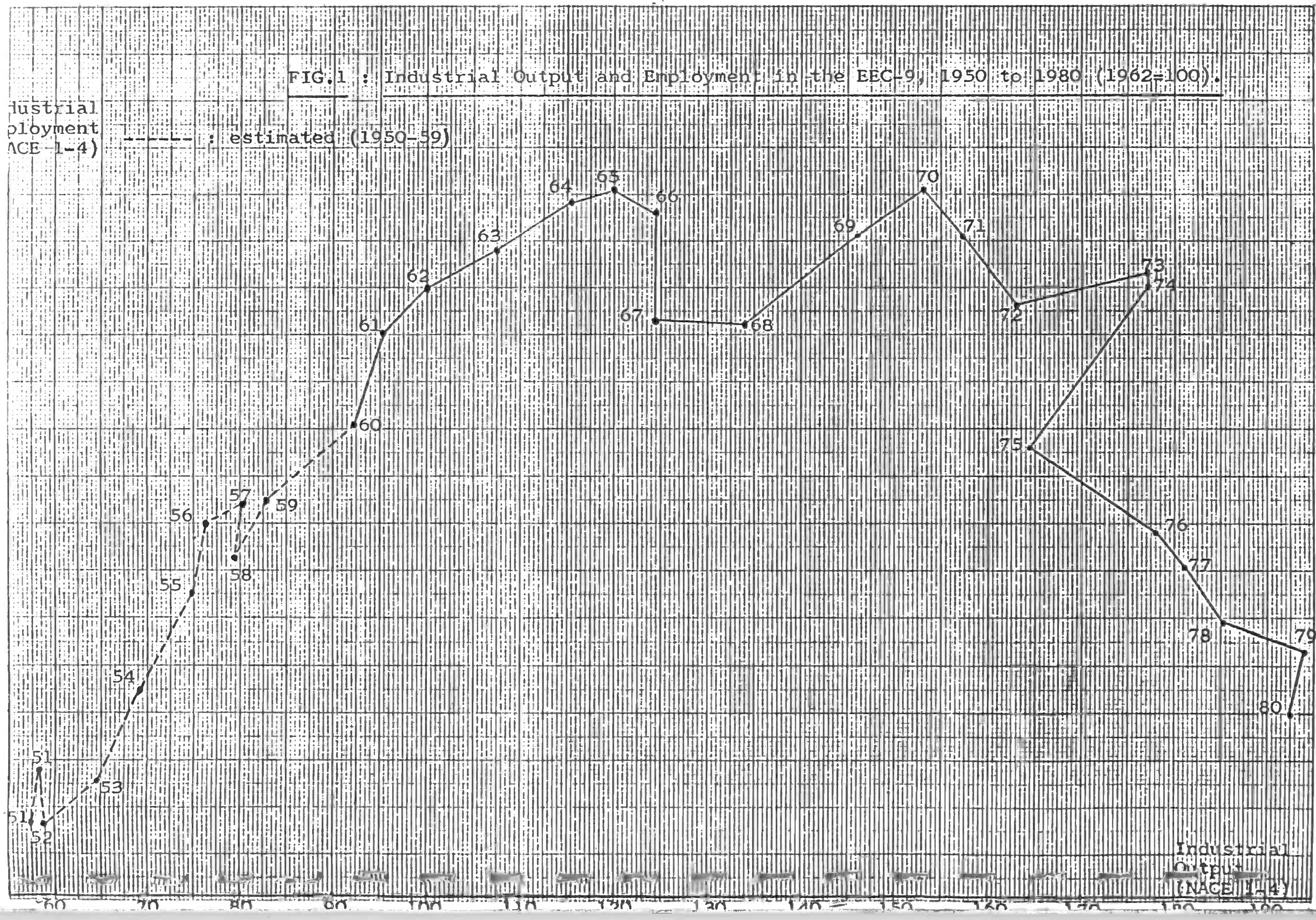
FIG.1 : Industrial Output and Employment in the EEC-9, 1950 to 1980 (1962=100).



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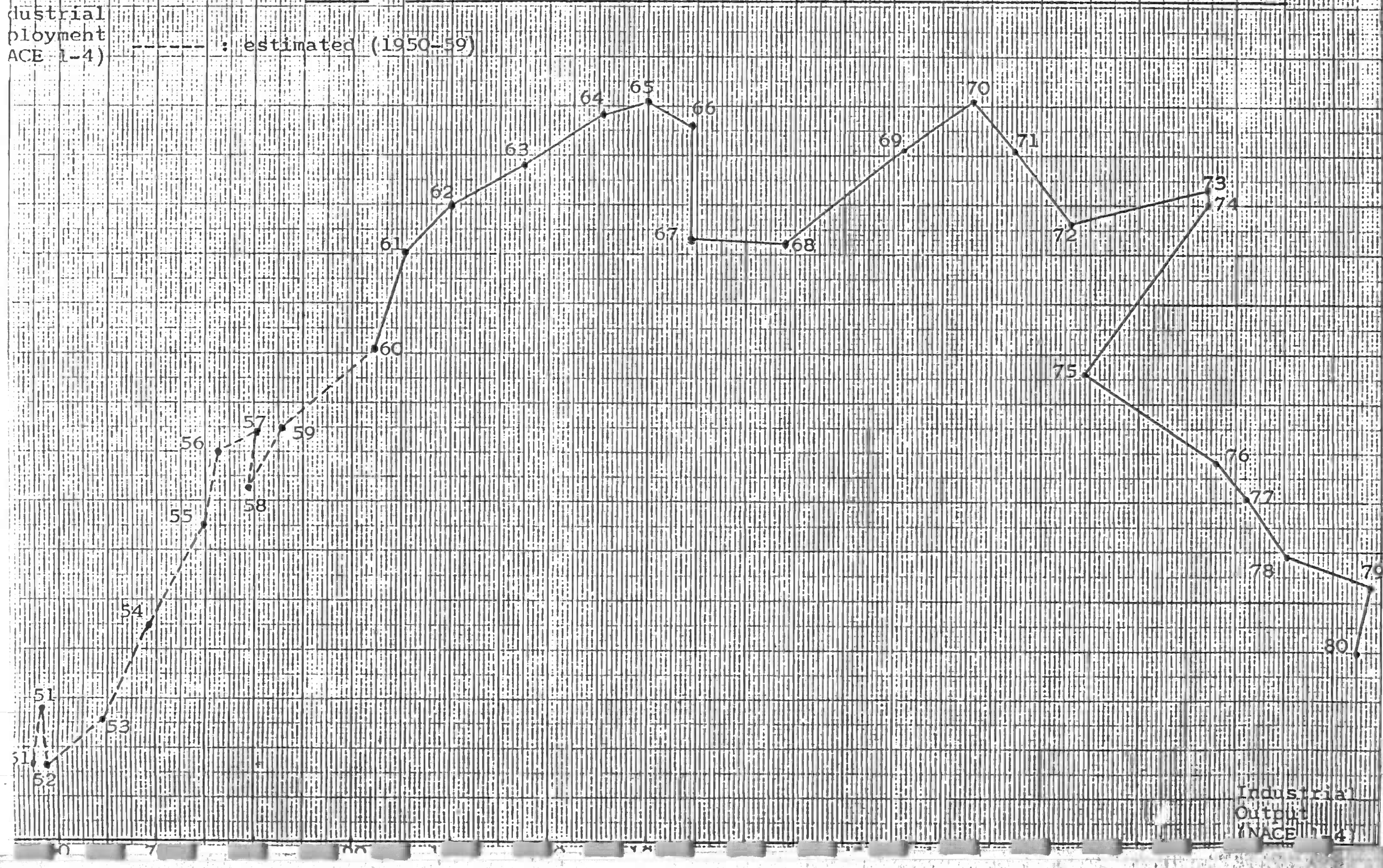

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Strategic Aspects of Chemical Industry Development in the Rapidly Industrializing Nations

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The chemical industry throughout the world is in a period of rapid change and major reorientation. This calls for a re-examination of the strategies followed by the newly industrializing countries in developing their chemical process industries.

Chemical products are essential for almost every aspect of a developing economy. Chemicals and chemical products are used in most sectors of manufacturing, in food processing, in civil construction, in communications, in military operations, in health care, and so on. Pesticides, fertilizers, drugs, paints and coatings, adhesives, plastics, rubber products, hydraulic fluids, etc., are all products of the chemical industry. Like steel and cement, chemicals are everywhere. Thus, a secure supply of chemicals is important to development.

While the ten-fold increase in world crude oil prices of the past eight years has been a challenge to the petrochemical industries of Europe, Japan, and to a lesser extent, the United States, it has severely affected the nascent chemical industries in developing countries. The world price of crude naphtha—upon which many new industries are based—has increased manyfold from 1973 to 1982. Thus, these industries, which contribute little to direct employment in developing countries, have also become major consumers of foreign exchange.

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Not only have the OPEC countries raised the price of petroleum, but they are themselves entering the chemical production business. As the major new units come on stream in the 1980s, they will be in direct competition with existing industries all over the world.

Needless to say, oil-producing countries in the chemical business can to some extent choose whether to extract their monopoly profits from oil or from chemicals produced from oil. Therein lies the possibility—if not the motivation—for chemical pricing policies that could undercut local industries dependent on imported naphtha for feedstock.

In light of the vastly altered world feedstock situation (and of the removal of the petroleum and natural gas price controls that have given the US chemical firms an advantage vis-à-vis Europe and Japan), the free world's major chemical firms are currently adjusting their own growth and development strategies.

For example, major chemical firms such as DuPont, Dow, Monsanto, ICI and Bayer have all stated their intentions to focus on the development and production of "specialty" chemicals in the 1980s. Produced in smaller volume, embodying higher value added, and reflecting greater contributions of technical expertise than the traditional bread-and-butter commodity chemicals, these specialities from the majors will threaten both the smaller chemical firms in the developed world and the emerging chemical industries in industrializing countries.

Finally, there is a growing consensus in industrialized countries that the production, use and disposal of chemicals pose major hazards to man and the environment that must be controlled by vigorous government action. Japan, the US and several European countries have recently adopted laws requiring testing and official notification prior to manufacture (in the US) or to marketing (EEC countries and Japan). Since they apply to imports as well as to domestic production, these and related environmental and public health protection laws set a high standard for the scientific and technical sophistication of the industry and government of a country that wishes to engage in international trade in chemicals. Furthermore, such sophistication is also required if a nation is to protect its own citizens and its productive natural resources from such hazards.

The circumstances of the 1980s are very different from those of the 1960s, when the dominant paradigm of chemical industry development emerged from the experience of such nations as Japan, India and various Latin American countries. It is interesting to explore the implications of the new circumstances for development strategy with respect to chemicals, highlighting the importance of developing technological capability along several dimensions as a key element in that strategy.

The Special Case of Rapidly Industrializing LDCs

The availability of raw materials and energy resources, capital, indigenous technological capacity and the size of the market are the principal determinants of any national strategy for the development of the chemical process industry (CPI). Countries differ in their endowment of these resources or in their ability to purchase them from other countries. Inputs to the chemical process industry would normally include petroleum, natural gas, coal, refinery by-products, renewable resources (especially biomass) and inorganic resources, such as minerals. While the OPEC countries have petroleum in abundance, they are very much dependent on technology from the more advanced countries. But they are able to buy the technology and engineering design and construction services needed. Other countries are not so fortunate. Several rapidly developing countries (also characterized as middle-income countries) are poor in petroleum and other raw materials needed by the chemical process industry, but still aspire to, and are now investing heavily in, the establishment of sizeable chemical process industries. Most are also deficient in terms of the size of capital needed for CPI development. Korea, Israel, India, Brazil, Portugal and Spain are examples of such countries. (See Table 1 for indicators on these countries.)

The strategies of these countries may be critically examined by the stages through which the chemical industry has passed in these and other countries. Five stages may easily be distinguished. It must be emphasized, however, that these stages are not necessarily sequential.

The Mixing and Compounding Stage

Even today, many countries in all the regions of the developing world import large volumes of basic chemicals which are simply mixed or compounded for sale to the ultimate consumer. This is very common in pharmaceuticals and pesticides and also in the fertilizer industry. A variety of synthetic resins are also imported and mixed

TABLE 1. Selected Indices of Target Countries.

Country	GDP per capita in US $ 1975	% Share of chemical industries of GDP 1975	1978	R&D/GNP 1977	Chemical R&D as a percentage of R&D in private industry 1970
India	137	1.8	1.9	0.5 %	10 %
Korea	1550[1]	6.5	5.4	0.67%[1] (1.5 %)[4]	36 %
Brazil	341	4.0[2]	–	2.8 %[5]	N/A
Portugal	1517	2.0	1.7[3]	0.27%	19.2%
Spain	2428	3.8	3.1	0.34%	33.1%
Israel	3608	N/A	N/A	2.0 %[4]	N/A

Sources: GDP per capita: *1976 Statistical Yearbook*, United Nations, New York; percentage share of chemical industries and R&D/GNP 1977: Calculations based on *Yearbook of National Account Statistics 1976* and *1979 Statistical Yearbook*, United Nations, New York; chemical R&D in private industry: *Industrial R, D & E in Spain 1977*, World Bank; *Statistical Characteristics*, OECD, Paris 1980.

Key: [1] = 1978; [2] = 1970; [3] = 1976; [4] = 1981; [5] = 1979.

Acknowledgment: The authors are grateful to Mr. Thomas Maier for his assistance in gathering data for this table and for background information on the chemical industry in the target countries.

for sale to the plastics, paints and varnish industries. If the size of the market does not justify local manufacturing, this is indeed an appropriate strategy. However, the opportunities to produce locally some of the more simple molecules would need to be continuously kept in mind if the country wishes to achieve technical capability in the CPI.

Import Substitution Stage

With the ostensible goals of saving precious foreign exchange and the concomitant acquisition of technical familiarity with the process, many developing countries have followed import substitution strategies in the past two decades. This strategy has unfortunately led them into a trap. The processes that have been imported are such that a permanent dependence has been created for imported raw materials and other inputs such as catalysts. In recent years, the rising costs of energy have forced costs to rise to non-competitive levels. What was seen earlier as a means of saving foreign exchange has frequently turned into a drain. Royalty payments for proprietary technology have also become an added burden. Key technologies in the process industries are not usually transferred to the developing country during this stage.

Indigenous Process Technology Development Stage

Indigenous technologies are usually developed by the LDCs to convert locally available renewable and inorganic raw materials into chemicals. Brazil's gasohol development is impressive by world standards. Both India and Brazil have developed several inorganic and organic processes to make chemicals which are now available for sale worldwide. Israel has developed a strong position in bromine and pesticides based on Dead Sea minerals. Export-oriented Korea has an ambitious program to develop its chemical process equipment industry.

However, processes used worldwide today in the basic chemical, petrochemical and pharmaceutical industries are still from the US, the developed European countries and Japan, which is now re-exporting technologies it originally licensed from these countries. There is however a drive by several of the developing countries to break into these sectors. Some penetration of the African and Middle Eastern markets by process equipment made in the developing countries has already occurred.

Production of Building Block Chemicals for the Petrochemical Industry and Petroleum Refineries for Gasoline

Stimulated by the desire to become self-sufficient in synthetic fibers and plastics, several countries have established petrochemical complexes based completely on imported naphtha. For example, the Korean petrochemical industry, built initially to serve the domestic market, operates efficiently and profitably. Plans for expansion of production for export are well underway.

Vulnerability to raw material supply interruptions and potential competition from other South Asian countries, which are engaged in similar expansions (for example, Indonesia, a member of OPEC, is entering petrochemical production, as are Singapore and Malaysia), may reduce the scope of these expansions somewhat. Built with internationally available technology and design and engineering assistance from leading foreign firms, the transfer of technology to local engineering groups has been minimal in these undertakings. Local engineering groups only do what is described as 'detailed engineering' with the core technology and conceptual design coming from the foreign contracting firm.

Stage of Indigenous Product and Process Innovation for the Domestic Market and Export

This stage usually requires the close collaboration of technically sophisticated local firms with universities and/or public research laboratories. It also requires a strong national base of chemical and biological science knowledge. This is the stage at which indigenous technological capability really counts. It is theoretically possible for the countries, such as India, Brazil, Korea, Portugal or Spain, with substantial groups of professional chemists and biologists to move into the area of high-value-added chemicals (additives, colorings, preservatives, pharmaceuticals, dyes, etc.) and this is indeed the announced goal of many of these countries. However, much of the technology for these chemicals is proprietary and licenses are difficult, if not impossible, to obtain. Besides, financing mechanisms, such as venture capital companies, do not yet exist in these countries to share in the risk of product and process development. Governmental involvement and support over extended periods may be needed to assist local firms to enter this highly competitive field of fine chemicals manufacture.

Technological Capability—Static and Dynamic Views

In order to adopt, adapt and develop chemical process technologies, a nation needs a base of scientific and technological capability encompassing several disciplines and activities, and especially competence in industry. A national strategy needs to be concerned with each of these and with the question of their most effective institutional home. Furthermore, a strategy needs to be concerned not only with the static question of the kinds of capability and their locus, but also with the question of the dynamics of acquisition of these capabilities. One way to categorize the elements of chemical capability is presented below:

The chemical and biological science bases provide the floor upon which all further activities are built. Strength in such fields as catalysis, organic synthesis, analytical chemistry and biochemistry is needed. These capabilities are relatively mobile, because they reside in the minds of academically trained scientists and in relatively inexpensive laboratory equipment. In many nations the university system can produce chemists and biologists with state-of-the-art training, or scientists can be trained in other countries.

Capabilities in *environmental measurement, evaluation and risk analysis* require perhaps the highest levels of technical sophistication of any of the capability areas.

These tasks require operation and maintenance of advanced precision intrumentation, data processing and analysis, and medical and biological understanding. Technical university graduates with advanced degrees in science and engineering are reasonably well-equipped to perform these duties, if their educational programs have emphasized experimental rather than theoretical research. Beyond allocation of such highly skilled people to this "non-productive" work, however, capability in this area requires a national awareness and commitment to consumer, worker and environmental protection.

Another element of national capability is a corps of specialists who can *identify markets* and who can *provide technical assistance to user firms*. Such specialists need not so much in-depth technical expertise as broad familiarity with the structure and needs of local industry, and understanding of local bureaucratic and indusrrial management practices.

The process engineering base is largely centered in chemical engineers who can specify process flow sheets and operating conditions and parameters, and who can supervise plant operations. Often bachelors' degrees or the equivalent are adequate for even sophisticated operations. However, universities are rarely equipped to graduate engineers who can contribute immediately to process engineering. Further, university faculty and government laboratory engineers rarely are prepared to participate directly and fully in such work. A period of industrial experience is essenrial.

Process Design and Construction

A closely related capability is in *process design and construction*. Such work usually involves mechanical and civil engineers and, to a lesser extent, electrical and materials engineers. Such professionals are concerned with a level of detail and application in concrete situations that is not encountered in universities and government labs. They are frequently found in specialized design and construction firms. Work in this area draws heavily on experience and accumulated knowledge gained from practice, including management of construction projects. However, even in the most advanced countries a large measure of this expertise can be "rented" through the world-wide system of firms that specialize in plant design and construction.

Another chemical technology capability involves *process control* and *optimization*. Specific skills range from instrument repair to sophisticated microelectronic design and computer modeling. Both skilled technicians and advanced engineers and computer scientists with industrial experience are needed. Fortunately, these skills are generalizable across a wide range of technologies and branches of industries.

In order to build and maintain a chemical industry, a country needs *skilled tradesmen*, such as welders, electricians and other types of technicians, who can work with exotic materials and with complex machinery and systems of control. While most countries have tradesmen in these fields and training institutions can augment their skills in specific areas, a period of apprenticeship or on-the-job training is necessary if such people are to work effectively and safely.

Equipment design and fabrication requires a wide range of practical skills and the support of supplier industries. It requires skilled tradesmen and designers. It also requires substantial capabilities in measurement, quality control and testing, as well as in materials handling and production management. Some of these capabilities can be learned in the classroom; others require years of experience.

The last, and very important, area of capability is the ability to *assess and decide among technological alternatives*. This capability requires an integration of technical training; experience in raw materials acquisition, marketing, business operations and labor relations, and a knowledge of international chemical industry trends. Thus, it requires the combined skills of a sophisticated engineer and an experienced business executive—a rare blend in any society and doubly rare in the private sector of newly industrializing countries.

Acquiring the Capabilities—A Dynamic View

Industrializing countries need to develop a strategy for the acquisition of capabilities described above. However, they face a substantial dilemma in getting started; without these capabilities an industry cannot be started, and without an industry, the capabilities cannot be developed. Thus, the experiences of many countries show that the only viable alternative is the participation of foreign firms in the development of their chemical industry, but this holds the risk of continuing technological dependence.

It is necessary to examine strategies and options that countries may find useful in managing the simultaneous development of: 1. a domestic chemical industry with limited participation by foreign firms, and 2. the technological capability needed to establish a relatively independent chemical sector over time. Observations in several countries are used to identify pitfalls to be avoided along the way and to suggest opportunities to make the best of a complex situation.

Strategies for Chemical Industry Development

As noted previously, a national strategy for chemical industry development needs to consider the nation's natural resource base, capital availability, market circumstances and technological capability. Among these factors for any particular country, technological capability is the most susceptible to modification through conscious policy choice. It also affects the choice of a successful strategy. Thus a chemical development strategy must consider both the existing state of technological capability and the ways in which that capability can be strengthened over time.

Table 2 illustrates the relationships among the elements of technological capability discussed in the earlier section and five possible chemical industry development options. The five development options correspond roughly to the stages in the classical model of development of a chemical industry. The table also indicates the institution in which the capability elements must be "learned."

Consider a strategy that emphasizes Option III, eventual development of a strong national capability. Clearly, academic and classroom experiences are

TABLE 2. Developing and Using the Elements of Chemical Technological Capability.

Institutions where capabilities are "learned"				Development options				
				I	II	III	IV	V
Academic and classroom training	Industry training and experience	Experience with local markets and conditions	Elements of technological capability	No significant chemical industry	Build industry under contracts with foreign engineering firms	Initial foreign participation with focus on indigenous capabilities	Strong national capability	Collaboration in international process industry development
✓			Chemical and biological science base	×	×	■	■	■
✓	✓		Environmental measurement evaluation, and risk analysis	×	×	×	■	■
✓	✓		Process engineering base	•	×	■	■	■
✓	✓	✓	Process design and construction	•	•	×	■	■
✓	✓		Process control and optimization	•	•	×	■	■
	✓		Skilled trades/technicians	•	×	■	■	■
✓	✓	✓	Equipment design and fabrication	•	•	•	×	■
	✓	✓	Use of chemicals in other industries	×	×	×	■	×
✓	✓	✓	Assessment and choice of technology	×	×	×	■	■

Key: ■ Major need; × Some need; • Little need

insufficient by themselves to facilitate all but the most rudimentary chemical industrial development. Industrial training and experience are the *sine qua non* for development. In the authors' judgment, only equipment design and fabrication skills can reasonably be left to foreign suppliers when a nation follows this strategy. But acquiring all these capabilities makes it unavoidable that a nation pass first through either Option I or Option II. This choice, in turn, is likely to be heavily influenced in today's world market conditions by a nation's raw material position.

If a nation is deficient in chemical raw materials, especially in petroleum or natural gas, then Option II, which involves building a domestic industry under contracts with foreign engineering firms, is unlikely to be appropriate. This will be so because, for the most part, the only technologies available from such firms are world-scale plant designs for producing bulk primary or intermediate chemicals. As noted in the introduction, a nation without raw materials is at a severe competitive disadvantage in such products. It must also import intermediates. Rather than follow this course, which was adopted in the last few decades by such countries as Spain, Portugal, Korea, and India, in today's world chemical environment, a newly industrializing nation without a substantial chemical raw material base might be well-advised to follow Option I, limit its chemical industry to a few compounds, and depend on imported chemicals to meet most of its needs.

However, if a raw-material-poor nation is fortunate enough to have very strong capabilities in basic science, process engineering and skilled trades, *and* if it has reasonable capabilities in process design and construction and in process control and optimization, it *might* consider embarking on the very challenging Option III (initial foreign participation with focus on indigenous capability) and trying to produce high-value-added specialty products. Following this course, a nation is making a bet that it can succeed in three key areas: 1. getting access to sufficient intermediate chemicals in the world market to serve as raw materials; 2. negotiating agreements on joint ventures and licenses that will facilitate later disengagement from foreign participants; and 3. managing to train and retain cadres of experts with the capabilities required to sustain a relatively autonomous industry. To the authors' knowledge, only Japan has succeeded in following this path to modern chemical industry development, and, of course, Japan commenced its redevelopment in the 1950s with strong, if badly damaged, technological capabilities, including a national emphasis on the production of qualified engineers.

Table 2 also has important implications for the raw-material-rich developing nations that are considering entering the chemical industry. Despite their raw material situations, such countries are often very limited in the kind of chemical industry they can develop by weaknesses in technological capabilities, unless they are willing to be almost completely dependent on foreign expertise. Such dependence may lead to undesirable political and social consequences for both parties. With one or two exceptions, not even the OPEC countries can afford not to optimize the returns to their oil and gas resources. So developing local centers of technological capability is important for them as well.

Summary

In summary, a number of elements of technological capability are central to national strategies of industrializing LDCs for developing a chemical industry in the 1980s. Countries which already possess a strong raw materials base and a commanding technological capability will dominate world trade in chemical products. Too great a focus on markets and financing to the exclusion of technology and the raw materials base in a nation's strategy is a sure road to disappointment and, perhaps, to failure.

MOD 13 *

THIRD WORLD INDUSTRIALISATION STRATEGIES IN A RESTRUCTURING WORLD ECONOMY: THE ROLE OF TECHNICAL CHANGE AND INNOVATION POLICY

(Report submitted to UNIDO Global and Conceptual Studies Branch)

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THIRD WORLD INDUSTRIALISATION STRATEGIES IN A RESTRUCTURING WORLD ECONOMY: THE ROLE OF TECHNICAL CHANGE AND INNOVATION POLICY

INTRODUCTION

In marked contrast to earlier periods, the major actors in the world economy have begun the decade of the 1980s with a profound sense of uncertainty over the likely course of future events. The principle economic reason for this unease is that since the late 1960s, the advanced industrial economies (AICs) have suffered a serious deterioration in economic performance. Government attempts to effect improvements through the application of orthodox and unorthodox policies have so far met with little sustained success. Short run forecasts for the 1981-1985 period offer little evidence of any immediate and substantive improvement and growth rates are not expected to go very much above 1.5%.

The AICs of course have not been alone in their difficulties. The developing countries (DCs) also experienced rather serious economic problems in the 1970s - a development which for many only made an already difficult situation much worse. There is little question that some of the problems were due to internal mismanagement. However, many were related directly to the poor economic conditions in the AIC and the generally depressed state at the world economy. Among many other factors rising energy prices have been particularly troublesome for the DCs, causing long term balance of payments crises in almost all non-oil exporters. Consequently, despite the relatively strong position of a few newly industrialising countries (NICs), the prospect of a return to earlier periods of relatively rapid expansion for many DCs in the near future are dim, with growth expected to be at or near zero in real terms.

These developments have contributed to an international economic situation that is very different from the 'virtuous' cycle of stability and expansion in output and trade characteristic of the post-war period.

It is notable that the malaise currently gripping the world economy is viewed by many as a direct result of structural imbalances and ridgidities in the economies of the centre countries. These structural problems were in part caused and in part exacerbated by drastic changes in parameters which defined the working of the world economy in the post war period. Among these, persistent inflation, rising energy prices and increasing exports of manufactures from the Third World are seen to be particularly important sources of tension and change. The predominant view is that the resolution of these structural problems will require a significant degree of change and adjustment within the AICs as they adapt to the new pattern of relative factor prices and the changed circumstances caused by slower economic growth while making way for the NICs and other DCs to take their place as major economic actors. Most observers recognise that adjustment must inevitably involve high social costs and that the process will be a long term one that has no certain guarantees of success. Indeed as a quick reading of the economic and financial section of any major newspaper reveals the nature and consequences of the (planned and unplanned) restructuring process that has already taken place in the AICs confirms the view that many difficulties still lie in the way of a smooth transition.

While the burden of adjustment may well be seen to lie primarily with the advanced industrial countries, there is little question that the deep integration of the developing countries into the world economy means that their fortunes are tied intimately to those of the developed world. As a result, there are a number of conduits through which developments and actions which take place in either of these groups can impinge upon each other. This condition of mutual interdepdnence has fostered an awareness among policy makers both in the AICs and the DCs that their freedom of action are inevitably constrained by their participation in the world economy. One interpretation of the effect of this situation is that the AICs and DCs have a strong justification based on their own self interest for seeking ways of jointly managing the period of transition and restructuring to ensure the best possible outcome. This reasoning has been a strong motivating factor behind the recent efforts of many international agencies to promote a dialogue between North and South on the problems of restructuring and reshaping the world economy.

Given the magnitude of the problems that face all countries at the present time, attempts to achieve collaborative solutions should certainly continue and even be increased. However, while we acknowledge the complex degree of interdependence that does exist between the advanced industrial countries and the Third World, it is also the case that the developing countries occupy an inherently weak bargaining position in the present world economic balance of power. This is so for a number of reasons which are well documented elsewhere and which have two important implications for our discussion. Firstly, the DCs can expect to face a set of economic conditions in the near future which they have played only a marginal role in determining and which will inevitably reflect the dominant role of the AICs and the principal actors within these countries. Secondly, we would argue that the DCs, though participating fully, should expect to achieve relatively little in the way of negotiated change which would require the AICs to make substantive alterations in their status quo in order to benefit the Third World. The failure in this regard of the Tokyo round of GATT, UNCTAD, UNCSTD, the recent UN energy conference and various commodity stabilisation negotiations bear testimony to this unfortunate fact - as do the current stalemates extant in the North-South dialogue and in renegotiation of the Multi-Fibre Agreement.

We believe these conditions strongly underline the need for DCs, individually and collectively to give utmost priority to their own independent efforts to achieve their developmental goals in an increasingly hostile economic environment. Hence the need for well planned, strategic responses to the problems and prospects posed by this environment is particularly urgent now even if current uncertainties make such planning very difficult. The costs of remaining overly susceptible to the vagaries of the world economy and the self-interest of the AICs will certainly be even higher in the future than previously. Third World policy makers have no doubt already discovered that the factors mentioned above - the current economic difficulties in the AICs and the public and private sector responses to these have fostered an economic climate very different from that which confronted them in the 50s, 60s and early 70s. There are many new elements to contend with that were not apparent 10 years ago - greatly increased energy costs and a depressed world economy only two of a much longer list. At the same time, the longer standing development issues of income distribution, maintenance of food self-sufficiency, oppressive dictatorial regimes and political inequalities.

FOCUS OF THE PAPER

There have been a number of recent forecasting exercises and "forward looking" studies which have attempted to take account of these changes discussed above. This has frequently been done through the analysis of aggregate trends in the wide variety of variables involved, in order to be able to give estimates of the future shape of the world economy and the position in it of the developing countries. The purpose of this paper is both more modest and more eclectic. While we start with a similar awareness of the complex nature of the factors impinging upon developing countries we shall be focussing much of our analysis on only one set of these - the role of technical change and technological development in the restructuring process and the implications of this for DC industrialisation strategies in the 1980s.

Technology and technical change have of course, always been important factors in national development and in the evolution of international economic relations. We have chosen to focus our discussion on these issues because of their historical importance and because we believe that they will play an even greater role in developments in the decade ahead. There are three elements to this belief which we will explore in the paper. Firstly, the behaviour of the technical change variable was a major determinant of the economic difficulties experienced by the advanced industrial countries in the 1970s. Secondly, given the likely future effects of the diffusion of some particularly important new technologies and the ongoing shift in AIC government policy towards more support for innovation we expect technical change to be a major determinant of AIC economic performance in the future. Thirdly, the success of DC industrialisation strategies in response to the restructuring process taking place in and controlled by the advanced industrial countries will equally depend on their grasp of the technology factor since this will affect not only their access to AIC markets but equally their ability to control the path of development of their own economies.

Of course technical change is neither an exogenous nor a neutral variable. The direction it takes and the effects of its introduction are determined by the decision of firms and governments and by the national and international economic, political and social context in which these decisions are taken. A principal interest in this note will be to explore the implications for the Third World of the decision regarding technical change strategies and innovation policies adapted by the public and private sectors in the AICs. Following directly on from that we shall be discussing how Third World industrialisation strategies will need to reflect a changed approach to economic relations with the AICs, and with other developing countries and to the acquisition and exploitation of industrial technology.

SECTION II INNOVATION AND ADJUSTMENT IN THE ADVANCED INDUSTRIAL COUNTRIES

Technical change and the innovation strategies adopted by governments and enterprises in the advanced industrial countries have been stressed by many observers as important elements in the restructuring process. They remain, however, uncertain quantities - both in terms of the nature of their impacts and in relation to the rate at which any associated changes in the national or international economy will take place. Past experience is a very imperfect guide to future developments in the area. Historical relationships between technical change and economic growth have broken down in the 1970s. Poor economic conditions have prompted firms to undertake innovative strategies which are quite different from those followed in earlier periods.

Despite the changes in their relationship with economic growth, technical change and the technological assets of a firm or country have become increasingly important determinants of their competitive strengths in international markets. The ability of a country to remain internationally competitive - at both the "high" and "low" ends of the market - is crucial to the continued well-being of its domestic economy. This may increasingly depend on both the technical change capabilities of the private sector and the ability of the public sector to marshall the necessary forms of support to nurture and encourage their accumulation. Hence government initiatives to stimulate innovation and encourage diffusion are certain to carry more weight in the future - and will possibly have a greater and more clearly identifiable impact than in the past. This section highlights some of the more important features of past and likely future developments in this area in relation to the advanced industrial countries.

A Brief Overview of the Underlying Economic Trends

A number of analyses of the recent economic performance of the AICs have amply demonstrated the principle features of the current crisis most relevant to our interests.* The magnitude of the problem (and the scale of the implications of it for the Third World) can be easily grasped by reference to Figure I - which shows the relationship between output and employment in the nine major EEC countries between 1950 and 1980. The period up to 1965 shows a consistent, positive relationship between output growth and employment growth. From 1965, this relationship started to change with an initial trend towards a pattern of 'jobless' growth from 1965 to 1970. In 1970, the pattern again changes to one featuring almost continuous negative growth rates in employment, which from 1975 to the present have been combined also with negative rates of growth in output.

As the graph indicates and Table I confirms, a steady rise in unemployment has been one of the most severe manifestations of the scale of the adjustment problems for AICs created by low growth in the 1970s. The fact that many countries are beginning to approach the unemployment levels of the 1920s with little signs of an early reversal of the trend suggests the possibility that the recession of the 1970s could already be taking on the characteristics of a 1980s style depression.

INSERT FIGURE I AND TABLE I

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* Here and throughout this section we draw heavily on recent work carried out at the Science Policy Research Unit, particularly Soete, 1980, 1981; Pavitt and Soete, 1981; Pavitt, 1980 and Freeman, Clark and Soete, 1982.

Persistent inflation, however, has been perhaps the most notable and dominant feature of the AIC economies in the 1970s. As with the declines in output and employment, 'demand-pull' inflation began to really take hold in the late 1960s in the midst of the US effort to fund the Vietnam War. It was given massive impetus by first the 1973 and then the 1979 oil price rises, though other factors - labour market ridgidities, government imposed cost-push pressures, etc. - certainly played a part. Whatever the precise combination of reasons, the end result has been a relentless upward march of prices quite unexperienced in the 1950s and 1960s. The severity of the trend can be gauged by the fact that during the period from 1974 to 1980, a number of AICs including the UK, Italy and France, experienced a rise in prices that exceeded the increases that occurred between 1953 and 1974 (Kaplinsky, 1982).

The persistence of inflationary pressures combined with rising unemployment and low output growth has, among other things, confounded economic theory over the course of the last decade. The predominant fear of the inflation component in these 'stagflation' conditions has caused governments to adopt a consistent bias against expansionary policies in favour of restricting demand. Indeed the elimination of inflation has been the overwhelming objective of AIC government policy for at least the last 10 years. The emergence of this 'new' orthodoxy with its myopic commitment to monetary dogma, has also undoubtedly been related to the politically expedient need to limit the gains which accrued to labour during the post war period. Hence, there seems little question that the restrictive policies followed in 1974-75 and even more drastically in 1980-81 - in spite of high unemployment and the deflationary impact of oil price rises - have contributed greatly to the severity of the current recession. The temptation is very strong to link the 1978-81 rise in OECD unemployment from 16 million to 24 million to AIC monetarist regimes and the private sector rationalisation tendencies which that mentality unleashes.

It is obvious that the strongly entrenched character of these structural conditions and the accompanying government policies have created a distinctly unfavourable environment for Third World development efforts in the 1980s. This is particularly true if we add to the recipe the incredients of slow growth in world trade since 1972 - estimated to be less than 1.5% in 1981-1982 and the strong tide of protectionism which has become a feature of the external policies of most DCs. These latter elements are contextual factors impossible to ignore in any analysis and we explore them further in subsequent sections.

The Role of Technical Change in National and International Economic Performance of the Advanced Industrial Countries

Here, however, we are more concerned with a set of distinctly interventionist supply-side responses emerging in the advanced industrial countries as a direct reaction to the malaise depicted in Figure I and Table I. These responses - embodied in analyses, reports and policy documents emanating from both the public and the private sector and from policy analysts - lay stress upon the potentially crucial role of technical change as a stimulus to renewed growth and expansion in the DCs (OECD, 1980; Carter, 1981).

The upsurge in interest in the role of technical change as a motor of economic growth has been based partly upon ex-post assessments of developments in the 1970s in the relationship between rates of innovative activity, economic growth and international competitiveness. Both national and international dimensions are involved. At the national level it is now clear that the deterioration in output and employment has been accompanied by an underlying decline in the rate of growth of productivity.* This can be clearly seen in Table II which shows industrial productivity growth in the 1970s for the 9 major EEC countries.

INSERT TABLE II

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* This is a trend which has not been picked up by some of the restructuring analyses. See for instance UNIDO, 1981, p.61.

Numerous explanations have been offered for these declines in productivity growth. Many of these are clearly related to the underlying causes of the recession and the correspondingly low rates of growth of output - restrictive responses to rising energy prices, enterprise expenditure on environmental related investments required by law, shifts of labour out of manufacturing into low productivity service activities, and the pressures of low demand-induced excess capacity forcing firms to work well below installed economies of scale. (Soete,1981; Dennison, 1979; Griliches, 1980).

Explanations related to changing patterns of technical change and industrial R & D have also been given a good deal of prominence. During the 1970s there were clear shifts in the pattern of R & D investment by the public and private sector in the OECD countries that contrasted somewhat with the trends established in the 50s and 60s. During that earlier period, there were consistent increases in R & D expenditure by both groups which correlated closely with improvements in productivity and high rates of economic growth. This relationship held between countries and across sectors - and even during the 1970s those industries with the highest growth in R & D expenditure - such as electronics - have experienced continued improvements in productivity (OECD, 1980)*. This relationship has not held up during the 1970s. The rate of increase in R & D expenditure declined dramatically as governments reduced the level of their direct support and firms shifted resources away from basic research and longer term projects towards more applied work with safer short term returns. This latter response is partly due to the retarding effects of the deflationary policies mentioned above on the propensity to take risks and on entrepreneurial initiative in general. Prospects of continued restraints on demand have undoubtedly lead to an increased lag in the commercial application of technical advances via the overall slow down in investment.** (See OECD, 1980; Soete, 1981; for further discussion of these points). Between 1959 and 1967 industry R & D increased

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* A number of studies at the macro and micro level have demonstrated this relationship quite clearly. See Black (1968) for US industrial sector as a whole, Mansfield (1965), and Brown and Conrad (1967) for firm and industry specific evidence and Rothwell and Zegveld (1981) for a more general review.

** Also see Griliches (1980) and Thomas (1980) who show a lack of correlation between R & D and productivity growth in the US in the 1970s.

by about two thirds - between 1967 and 1975 there was hardly any increase in real terms (OECD, 1981). This can be seen by reference to Table III.

INSERT TABLE III

There is also a growing interest in the structural explanations based on the work of Schumpeter, which link the difficulties of the 1970s into a much longer pattern of upswings and downswings in economic activity caused by the incidence of major technological breakthroughs and the pattern of their effects on investment and employment in the economy. (See Freeman, 1977; Clark, Freeman and Soete, 1981; and Freeman, Clark and Soete, 1982). See also UNCTAD, 1981, Chapter .

While these technical change related explanations have found an increasing degree of acceptance among formerly sceptical observers this is by no means a uniform view. The conclusions of this area of work are not yet sufficiently developed to allow the formulation of normative policies regarding technical change and the role of technology in international competition. Certainly, we do not imply that a simple policy of increased investment in innovation and R & D will lead directly to higher rates of economic growth. There are clearly many other factors at work whose importance we do not seek to downplay. However, the arguments in support of an important causal link between those factors are persuasive, particularly if the evidence on the role of technical change as a determinant of international competitiveness is considered.

In this case, there are two sorts of interaction to make note of. The first centres on the relationship between the export competitiveness of manufactured goods and embodied technical change. Recent research carried out at the Science Policy Research Unit has established a strong positive correlation between the two factors. Using patents registered in the US as proxies for the level of innovative activities taking place within a country Soete (1980), Pavitt and Soete (1981), have shown that there is a clear relationship between patent share (in the US) and world market share for manufactured exports. Figure II and Table IV summarise the results of this work. Figure II plots patents registered in the US by Sweden, Italy, France, the UK and West Germany against their shares of manufactured exports for 5 years

- 1899, 1913, 1937, 1965 and 1975. As can be seen, the relationship is revealed rather strikingly. Table IV shows the results of a more rigourous test of this relationship. For 40 industries, exports per head for all OECD countries (except Iceland, New Zealand and the US) were regressed against patents registered in the US between 1963 and 1976. The grouping shows strong correlation for capital goods industries experiencing high rates of technical change, and less significant results for consumer and intermediate goods where technical change is less dynamic and based on diffusion of innovations originating in the capital goods sector. Although there are methodological issues that arise in relation to this type of analysis (which are dealt with extensively in the original papers) the results and supporting analyses suggest that the degree of international competitiveness is strongly based on technical change and hence on the amount and quality of innovative effort by a country's firms.

INSERT FIGURE II AND TABLE IV

The second relationship we would like to highlight rests on the "technology gap" based explanations for the high rates of productivity improvement and economic growth that occurred in Europe and Japan in the 1950s and 1960s (Soete, 1981a). In these arguments, the existence of a technology gap between Europe/Japan and the US in the early 1950s, spurred governments and firms in the former countries to embark on a sustained effort to close the gap (for fear of their domestic industry being swamped by US strength built up during the war (Soete, 1981b, Maddison, 1979). Sizeable investments in R & D and importation of technology (with extensive public sector support) succeeded in improving labour productivity to such an extent that in many sectors the "gap" was narrowed down considerably or even disappeared by the late 1960s (except in sectors such as electronics which in the US received considerable public support as well during this period). As the gap closed, rates of productivity growth slowed as most of the countries approached the technological frontier achieved by leading US firms (Gomulka, 1971; Cornwall, 1977; Pavitt and Soete, 1981).

At this point, several other developments began to impinge upon the established pattern of international competition between the OECD countries. Firstly, the general downturn in overall rates of growth obviously served to greatly heighten the degree of competition between established competitors to maintain (or increase) their share of a more slowly growing pie. Moreover, convergence in the levels of technological sophistication attained by the AICs meant that there were more firms and countries capable of entering the market on price grounds alone. Finally, pressure began also to be perceived, if not really exerted, from the newly industrialising countries vis a vis their exports of manufactures at the bottom end of the scale of technological sophistication.

The combined effect of these developments has been to foster conditions of more intense technological competition between the OECD countries than had existed before (Soete, 1981b). This phase of international competition is expected to continue throughout the 1980s, at least. It has two important characteristics. Firstly, slow growth and depressed demand has placed a premium upon cost-reducing innovations particularly in the capital goods industry as a means of servicing end-user demands for rationalisation investments - as opposed to expansion or replacement investment. To succeed as exporters and to maintain a domestic market share under these conditions implies the need to have a national capability to produce these sorts of innovations - both at the "high" and "low" ends of the market (OECD, 1980).

Secondly, competition in the consumer goods and engineering products industry is increasingly based on a combination of price/quality/performance factors rather than just the price factor. This pattern of demand is likely to prove most suitable to suppliers who have a product innovation capability that goes beyond simple product differentiation and can incorporate new features (and new products) without substantially increasing unit prices. The evidence for this trend is obvious for the wide range of new and improved consumer products, where the use of microelectronics has improved and expanded performance capabilities to such an extent that these have completely superceded products based on earlier technologies. In engineering goods, research into the unit value characteristics of AIC engineering exports has demonstrated the importance of having a product innovation capability to be a successful exporter. The poor performance of the UK and the excellent export record of West Germany in the engineering sector has been linked directly to the latters ability to upgrade quality via substantive technical changes rather than relying as the UK has done on price alone (Saunders 1978, Rothwell and Zegveld, 1981).

It is significant that both of these trends have gained strength during the advent of microelectronics and as the implications of this technology began to be grasped by both private industry and government policy makers in the AICs. It appears to us that these trends are likely to be closely interlinked in the future and we believe that taken together, they are particularly important indicators of the changed nature of the international competitive environment that will be faced by LDC exporters in the 1980s. Success in this environment will increasingly be based on technological factors - of which the ability to innovate with microelectronics will be an important one. This interface as we shall see is already the objective of public and private sector policies. Moreover, although in both cases the evidence supporting these tendencies is as yet more prevalent for products and processes with a higher degree of sophistication and complexity, evidence which we explore below suggests that they will become increasingly important in those product categories where LDCs have traditionally relied upon labour cost differentials for their comparative advantage.

* * * * *

Adjustment Policies in the AICs: The Context for Innovation

The arguments presented above regarding the importance of innovation and technical change both as a motor of economic growth and as a source of international competitiveness have direct implications for AIC government policies in the 1980s. It has been argued in a number of contexts that there is now a clearly defined need for these countries to commit more resources to stimulate technical change and diffusion (see Freeman, 1978, as a good example). These measures can both help their economies to break out of the current recessionary cycle, and perhaps more importantly from the point of view of individual governments could be a key element in maintaining international competitiveness and reaping the resultant domestic benefits in terms of employment generation and balance of payments contribution.

In laying stress upon the link between innovation, economic growth and international competitiveness within the AICs we are nevertheless aware of the obvious limitation in implying that there are single factor explanations for any development in any economy. The factors making for industrial "success" within the AICs are many and varied - culture, educational levels, historical precedent, government policies, entrepreneurial attitudes, the organisation of production in the private sector, etc. There is likely to be no single key to success or cause of failure. Innovation, or lack of it, is only one of these, albeit as we have tried to argue, an increasingly important factor.

Likewise there is also a very wide spectrum of industrial policies have been tried by all the AICs trying to deal with the complexities of stimulating their economies to make the necessary adjustments to the new economic conditions which have emerged over the last decade. Measures specifically concerned with innovation - themselves a broad category - are really only one subset of this larger group which are briefly listed below.

For analytical purposes the wide variety of industrial adjustment policies adopted by the AICs can be classified in many ways. However defined, the range of policies adopted usually include the following:

- measures based on adjusting the available supply of capital resources e.g. start-up loans and loan guarantees, tax incentives, differential investment allowances;

- policies dealing with labour market adjustment, e.g. unemployment and redundancy pay, various training and retraining schemes, support to enhance the geographical mobility of workers, employers compensation, etc.

- action taken in relation to trade-related problems e.g. various export promotion schemes, support for overseas visits of businessman, commercial protectionist policies,* support for establishment of subsidiaries overseas etc.

- policies to support sectoral restructuring and development; e.g. support for firm level rationalisation measures, credits for equipment purchases, procurement arrangements, special consultancy services, sectoral reorganisation, special measures to improve competition, etc.

- finally there is support for innovative activities and technological development; e.g. direct and indirect support for R & D in public and private sector, product development assistance, programmes to aid diffusion of innovations, promotion of university - industry cooperation, procurement policies, etc.

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* Traditionally, commercial trade policy was normally excluded from consideration as an industrial policy but the distinction is hardly recognised (or recognisable) any longer.

In addition, these policies can be combined in different packages and have often been given a regional slant in order to help a particularly hard hit part of the country (e.g. the Yorkshire textile industry) or to promote the concentration of fast growing industries in one location. Small and medium sized business have also often come in for special support under these schemes because of the professed belief in their importance in innovation and employment creation (NEDC, 1981).

We do not wish to dwell too long here on the specifics of the policies followed by individual AIC governments as these have been covered in detail elsewhere. (See Renshaw, 1981; and UNIDO, 1981a). However, these recent reviews do point up a number of features which are important for our interests and which we summarise briefly below.

One clear fact which emerges is that the relative importance or emphasis that AIC governments have given to innovation policies has varied widely since the war - even given the dominance of the "technology gap catching up" mentality mentioned earlier. This suggests that despite the evidence presented earlier on the relationship between R & D and innovation and economic performance there is a real danger in assuming that government innovation policies of the last decade have (a) had the effects intended by their drafters, and (b) that these policies were in some sense more or less important than other industrial policies. Difficulty in equating the use of a particular policy with a specific identifiable outcome is a problem which plagues not only the evaluation (and hence design) of innovation policies but applies equally across the board to the whole area of industrial adjustment policies. Recent analyses of AIC adjustment policies (including support for innovation) have found it fiendishly difficult to come up with any generalisable conclusions regarding the impact of these policies. (de Bandt, 1981; UNIDO, 1981a; OECD, 1979).

The difficulties inherent in making any sort of cause and effect analysis are borne out by discussions in the literature of the impact of so-called positive and negative policies of adjustment. These point out that within the wide range of policies used it is relatively easy to make a clear distinction between the two extremes of positive and negative adjustment - positive policies are those where the aim of the measures is to facilitate adjustment by providing information, advice and training to managers and workers as well as stimulating the development of new activities and new products through support for R & D, marketing, etc. Negative policies on the other hand are those measures which enable non-competitive activities to be kept in existence through the provision of trade protection, and employment and operating subsidies. (de Brandt, 1981).

However, there is unfortunately a wide grey area between the two extremes in which the policy measures which are adapted are likely to be positive and/or negative according to the circumstances surrounding the specific case and "there may even be a difference in this respect between intentions and the actual results" (de Brandt, 1981, p.114). The reasons for this lie in the inevitable gap between the a priori theoretical justification for intervention and the practical inclinations which inevitably dominate policy making the face of real and immediate problems. All of the AIC countries are ostensibly committed in principle to the notion of free trade and non-intervention. There are, however, important philosophical differences between them regarding the degree to which they rely on this principle to guide their interventions.

Unfortunately, there is little decisive empirically documented guidance as to whether more intervention has been better in any objective sense than less intervention. For instance the Federal Republic of Germany, Europe's most successful economy, is notable for its generally limited governmental desire to intervene. When this does occur it usually only takes place with a view towards facilitating rather than opposing the working of market forces. France, on the other hand, which is also a "successful" European country has adopted a much more centralised approach that has strong "planning" elements particularly in relation to influencing conditions and activities within major sectors and companies. Other countries in Europe combine different sets of intervention philosophies and packages of policies with both good and bad economic performances; with England having the dubious distinction of enjoying a government of staunch free market philosophers, while at the same time having the most extensive degree of state involvement in Europe, and yet, the country is arguably one of the weakest AIC economies.

Faced with this combination of non-sequitoral successes and failures it is, firstly, easy to endorse the view that historical structural factors have played a vastly important role in determining the performance of individual AICs in the 1970s. And secondly, one suspects that pragmatism (with more than a slight nod to political expediency) has been a much stronger motivation factor underlying the actions of AIC policy makers than theoretical justification. This view is stongly confirmed by the failure of most governments to justify the (theoretically) contradictory aspects of their policies; particularly as we shall see in the area of protection. Not surprisingly perhaps there is a strong consensus that by and large AIC adjustment policies have not had the overall beneficial effects that were intended - at best they have facilitated improvements where the underlying conditions were already leading to favourable developments and at worst may have increased the overall negative effect of a deteriorating situation. (de Bandt, 1981).

This degree of equivacy (and even agnosticism) on the part of the analysts involved may no doubt reflect the complex reality which their analyses reveal - if so then this certainly poses real problems for AIC policy makers trying to determine a set of guidelines for intervention based on past experience. This particular problem is not our concern in this paper. Unfortunately the impasse also poses difficulties for anyone trying to unravel the implications of AIC adjustment policies for the Third World. This is partly because of the very real complexities involved. However, the lack of any clear analytical framework onto which subsequent analyses can build is also due to the fact that the initial restructuring analyses have been undertaken without recourse to a specific enough set of criteria about what constitutes a success unless one adopts a purely Paretian viewpoint of the world economy - which we do not what constitutes failure from the point of view of the Third World. Never-the less, even though the overall impact of adujstment policies on the AICs is difficult to ascertain, it is in fact possible to point both to emerging trends and to some very specific examples of policy intervention which have had or will have direct effect on DCs - regardless of their effect within the overall context of the former countries.

As already noted, we believe that the innovation policies currently being followed by the AICs are one of the elements likely to be an important variable facing DC policy makers. There are a number of reasons for this which we explore below. However, before discussing what we see as some of the important developments in this area, we need to redefine the concept of innovation policies slightly. As noted above, innovation policies per se are considered to be only one subset of AIC industrial adjustment policies. In fact, many elements which fall under the other policy headings described above can be used to facilitate the process of innovation within the firm, sector or economy. Training and education schemes are clearly crucial, as are specific sectoral support programmes which can include both a geographical element and a firm size component. Government backed capital contributions have become increasingly essential to the establishment of large scale R & D units or productive entities whose activities or output in turn stimulate innovative activities downstream in other sectors. Likewise many other aspects of government policy such as regulations regarding the environment or trade, fiscal and monetary policies can have direct or indirect effects in the process of innovation. Obviously these linkages are present between all areas of adjustment policy; however, we believe their interconnectedness in the area of innovation is particularly important to grasp when discussing the issues from a DC perspective. Hence we have in mind the effect of this whole complex of direct and indirect measures when we discuss the trends and impact of AIC innovation policies.

Innovation Policies in the AICs: Emerging Trends

We have singled out innovation policies for emphasis because we believe that some important shifts are taking place in both the orientation and nature of the measures being implemented and in the overall context in which this is taking place.

We have noted the rising tide of voices putting the case for a greater degree of more generalised government support for innovation within the AICs. The study by the OECD (1981) for instance makes the case in the most emphatic terms for the OECD countries. In addition to this sort of "advisory" literature there does seem to be some evidence that governments are themselves taking steps in this direction. Rothwell and Zegveld (1981) in reviewing a number of recent DC government commissioned reports on innovation also show clearly the significant degree of unanimity in the proposals and analyses governments are receiving on this point. The studies evaluated by Rothwell and Zegveld were all part of ongoing reviews of innovation policies by the governments involved.* While we cannot be certain that all the recommendations made will be implemented it is at least arguable that they will be accorded serious attention in the processes of policy formulation that follow. Tables V, Va and VI summarise Rothwell and Zegveld's assessment of the principle features of these reports. These authors do criticise certain aspects of these studies because of what they view as their misplaced emphasis on some aspects of innovation policy vis a vis others. However, the nature of these reports and the trends cited above do constitute important evidence of an emerging tendency towards increased emphasis and support for innovation measures by AIC governments.**

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* Canada: Forging the Links: A Technology Policy for Canada, Science Council of Canada, Report 29, Ontario, February 1979.

Japan: The Role of Technology in the Change of Industrial Structure (abstract) Industrial Research Institute, Japan, April 1978

The Netherlands: Summary of the Government White Paper on Innovation, Science Policy Information Department, The Hague, 1979

Sweden: Technical Capability and Industrial Competence: A Comparative Study on Sweden's Future Competitiveness, IVA Royal Swedish Academy of Engineering Sciences, Stockholm, June 1979

United Kingdom: (1) Industrial Innovation, Advisory Council for Applied Research and Development (ACARD), London, 1978. (2) Technological Change: Threats and Opportunities for the United Kingdom, ACARD London, December 1979

United States: (1) The US Domestic Policy Review on Industrial Innovation, (interim report), May 1979. (2) Advisory Committee on Industrial Innovation, Final Report, United States Department of Commerce, Washington, September 1979. (3) The President's Industrial Innovation Initiatives (fact sheet), Washington, October 1979

** There is inevitably likely to be some debate over whether these steps are enough or are effective at all relative to what is required - this debate is of little interest here since we are concerned with the implications of the overall trends for the Third World.

INSERT TABLES V AND VI

In addition to this a priori evidence of support for more emphasis on innovation measures, there also appears to be actual movement in this direction on the part of the governments themselves. More importantly, there has been a significant shift in the focus and in the mode of application of policy instruments.

In general terms this shift has tended to be towards the increased sectoral use of specific interventions. In the early part of the decade, the tendency towards sector specific policies was established primarily in relation to the use of "negative" adjustment assistance. This trend reinforced by the industry crises resulting from the 1974-76 recession, although there was apparently a brief move towards broader "horizontal" measures which would in principle be available to all industries. (NEDO, 1981).

However, since 1977-78 there has been a shift back towards sector specific assistance for problem industries. More importantly a greater degree of selectivity is also currently being applied in the use of positive adjustment policy wherein the <u>innovation</u> component in these policies is reckoned to be receiving much more emphasis (NEDO, 1981). At the same time, as we discuss below, the application of innovation policies has started to become more specific and well-defined. Both of these tendencies have suggested a shift in the use of adjustment policies in a 'package' form which could, certeris paribus, enhance the prospects for an improved rate of innovation and technical change within the domestic economy. One of our principal reasons for arguing this point is the particular nature of the shift in focus mentioned above. This shift has seen government support for innovation increasingly being concentrated on major growth sectors which now seem to be dominated by "generic" technologies rather than traditional product areas (NEDO, 1981).*

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* This shift is perhaps not surprising given the amount of attention recently devoted to the likely impacts of these technologies. Certainly, the importance of these technologies has been mentioned by every one of the adjustment studies reviewed for this paper even if they do seem to underestimate the significance of the changes which have already taken place. See de Brandt, 1981; UNIDO, 1981a and b; OECD, 1981, Renshaw, 1981

Hence the increasing amount of government support for activities associated with the so called new technologies in the areas of microelectronics, bio-technology, energy and communications. As we shall discuss below, these technologies, particularly microelectronics, not only involve significant areas of innovative and productive activities in their own right but are equally certain to be a major stimuli to innovation in downstream industrial activities and an important factor in the international competitiveness of the innovating firm or country.

As a result of the focus on these areas of future growth, the application of government innovation policies has become much more selective while at the same time taking on a sectoral character which is much wider than had previously been the case. Hence almost all governments now have a variety of programmes designed to enhance the spread of new technology-related innovations throughout industry* - most of these are related to microelectronics and communication technologies but support for new energy technologies and for bio-technology is also increasing rapidly. (See, Hoffman, 1982 on the latter technologies.)

There has also been a tendency (noted by both de Bandt (1981) and NEDCs (1981) review of European industrial policy) for governments to use measures set up within a "horizontal" framework to promote the use of new technologies in a wide range of industries - these include particularly support for R & D subsidised loans for equipment purchase and public procurement policies. In addition there have also been moves toward a more selective use of longer standing programmes in the areas of manpower and training programmes, investment support and regional assistance with the same objectives.

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* The UK, in 1978 established the microprocessor application scheme under which $110 m was made available for training programmes, industrial consultancies in microelectronic application, and application R & D - this programme has recently been increased substantially and new elements introduced such as specific support for the use of CAD systems in industry. (See, Hoffman and Miles, 1981 for details of other UK programmes. The second phases of FRG's Data Processing Programme had a similar but more ambitious focus. See Grant and Shaw 1979), while France's Information de la Societe programme also had provisions for application of diffusion support. See EEC, 1981 for details of these programmes.

SECTION III JOINT INTERACTIONS AT THE SECTORAL LEVEL

In the above comments we have highlighted the emerging tendency of AIC governments to provide greater and more focussed support for domestic innovation. The significance of such efforts for our analysis does not lie solely with the explicit effects of these policies alone on DCs - though there are some that are both immediate and obvious. More important is the fact that these are taking place within an overall context characterised by concurrent developments in other areas. We have already mentioned some of these - the general increase in government awareness of the relationship between technical change and economic growth; the pursuit of deflationary policies to reduce demand; the role of the current recession in building up pressures on firms to cut costs and to make "rationalisation" type investments; and the shift towards a higher degree of technological competition in international trade in manufactures. We believe these developments, which we have discussed in fairly aggregate terms, will enhance the potential impact of AIC innovation policies and technical change in the restructuring process. Yet, at the same time these trends also contribute in a general sense to an international economic environment which is distinctly less favourable to DC industrialisation efforts than earlier periods, particularly if these effors are aimed at achieving export-led growth.

This can perhaps be seen more clearly if we turn our attention to some of the more specific factors which emerge out of this context and which have more direct and obvious implications for DCs. Again we have already highlighted some of these the effect of radical technical advances in the areas of microelectronics, bio-technology, etc. the emergence of highly protectionist trade regimes in the AICs; the "restructuring" response of international firms to the current crisis, and so on. Given this confluence of factors, it would clearly be a mistake to isolate our particular concern with AIC innovation policies too far away from the overall context provided by these other elements. Though analytically convenient, this is unrealistic in policy terms since DC policy makers will have to respond to the totality of conditions defined by the joint interaction of all these factors. Hence they need to be able to assess how and why the joint interaction takes place.

In the discussion that follows we try to highlight how this joint interaction is actually taking place in practice to try and shed some light on the multifaceted nature of the problems that the emerging trends in technical change and AIC innovation policy pose for DC policy makers. We will do this by referring to developments related specifically to the "new" technologies of microelectronics and bio-technology. We have chosen to draw examples from these areas for two reasons. Firstly, apart from the fact that both areas have been the subject of recent research by the author, we feel that a closer look at these technologies presents a particularly good opportunity to illuminate many of the issues we have been discussing so far. Secondly, we believe that the new technologies, particularly microelectronics, are destined to play a major role in shaping the future structure of the world economy and in determining the relative roles of different countries within this. While this notion is certainly acknowledged by the restructuring debate we believe it would be a positive contribution to bring the issues more to the forefront since these technologies could conceivably change many of the "rules of the game" on which the debate has been conducted so far.

Technical Change and Structural Shifts in the Microelectronics Sector

Of these new technologies, microelectronics has so far had the greatest impact and attracted the most attention. All of the elements mentioned above are present - rapid technical change, massive and direct government intervention, the potential for a significant impact on the international division of labour through the actions of international firms, "facilitating" government policies in trade and other areas, etc. While these elements no doubt co-exist in other sectors, their combined presence within electronics is significant because of the acknowledged importance of the sector in the future. It is by now a common observation that microelectronics is destined to play a major role in the world economy because of its potential to effect far reaching changes in the commodities that societies consume and in the underlying production processes. (See Nora and Minc, 1978; Forrester, 1981).

Rapid technical change has lead to substantial improvements in the range of functions that can now be performed electronically and to a continual and dramatic reduction in costs per function. These developments have already resulted in a phenomenal expansion in the use of electronic products and both trends are expected to continue and even accelerate. As a result most observers expect that the greatly increased demand for microelectronic devices will lead the electronics industry to become one of the most significant in the world during the next decade as shown by Table VII.

Table VII World Electronics Production
(current US $ Billion)

1965	1970	1975	1977	1981	1985	1991
Actual				........Estimate.......		
38	58	84	108	150-368*	230-560*	845*

Source: World Bank, 1980
* Mackintosh, 1980

Taking the lower figures for 1980-85, the table suggests a real rate of growth of between 8-10% a year - a rate which is far greater than most other sectors but which is regularly surpassed by sub-sectors of the electronics industry.* To provide a context, the current annual world output of steel is valued at about US $230 billion - the electronics industry already easily surpasses this and is expected to overtake the automobile industry as the world's largest to become "the main pole around which the productive structures of the advanced industrial societies will be reorganised." (OECD, 1979).

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* For instance, sales of computer aided design systems increased at a compound rate of 85% between 1976 and 1980 (Kaplinsky, 1982).

Developments in semi-conductors lie at the heart of the electronics industry. It is widely acknowledged that the evolution of the semi-conductor industry has been continually associated with government intervention by AICs. Indeed the presence or not of intervention has been directly linked with the relative degrees of success or failure of the industry in the OECD countries. (Dosi, 1981).* In the US government through the military and space programme involvement in research financing and semi-conductor procurement deeply affected both the supply and demand characteristics of the semi-conductor industry. Particularly in the early stages of the industry, these programmes were decisive in determining the direction of technical change, in allowing the private sector to count on the planned expansion of demand necessary to achieve scale economies, and by stimulating a vast accumulation of knowledge and expertise in the private sector. All of these elements, plus the normal workings of a highly competitive market helped give US industry a firm base for its early dominance and for the technological leadership it still enjoys in major product areas.

In addition to its support for R & D, etc., the US government also facilitated early industry moves towards assembly in LDC's** by the passing of offshore tariff provisions, 806.30 and 807.00 in the US

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* Much of the discussion in this section on the role of government intervention in electronics is based on the work of G. Dosi currently with the Science Policy Research Unit, see Dosi, 1981.

** By 1971, 43 US electronics firms had established "off-shore assembly activities in South East Asia and Mexico. The pressure of competition combined with the advantages of cheap labour and government incentives resulted in a continued mad rush so that by 1974 "all the major West-European and Japanese firms had set up such plants in South East Asia" (Parthasarathi, 1978). In Mexico alone, 168 branches of electronics firms were located in the border areas by the end of 1973 (Minian 1978).

Tariff Law of 1972.* As we shall discuss below, the involvement of certain LDCs in the international division of labour in electronics as a result of the existence of off shore tariff provision has important implications for their capacity to respond to the structural changes predicted for this industry in the 1980s. While these provisions obviously do not fall directly under the heading of innovation policy there was a significant interaction at work. It is clear that the early international division of labour in the industry was essential to achieving the optimal economies of scale (and hence unit cost reductions) that were possible with the process technology in use at that time. This in turn allowed the industry to gain valuable learning experience, access to markets, and a substantial return on investment - all of which were necessary to allow the industry to advance to the next stage of technological development which includes automated assembly.

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* Under these provisions, import duties are imposed only upon foreign value-added when domestic materials are sent abroad for further processing and then reimported. In the early 1970s imports of electronics demonstrated particularly impressive rates of growth under these tariff provisions, increasing from 10% of all imports under 806.30 and 807.00 in 1965 to 26% in 1974.

Within this group, imports of semi-conductors and other components grew exceptionally fast both as a percentage of total imports under these clauses (from 3.3% in 1966 to 13% in 1977) but also as a percentage of total US imports of these products. Already by 1969, imports of electronic memories under item 807.00 accounted for 98% of all imports of these products, semi-conductors and parts accounted for 96%, and television receivers and parts took up over 75% of total imports. By 1974, total value of imports of these products into the US had grown quite dramatically from $49.8 million to $961.3 million. (Parthasarathi (1978)). Similar rates of growth of DC imports under offshore assembly provisions are reported for the Federal Republic of Germany and the Netherlands, where between 1966 and 1972 the annual import growth rate figures were 36% and 39% respectively. (Finger, 1975, cited in ESCAP, 1979).

Government intervention in Japan was as extensive as in the US but followed a very different pattern since there was no involvement of the military in direct support for the electronics industry. The policies of MITI, the principal government agency involved, can be seen to be directly responsible for creating the conditions which have allowed Japanese firms to close the post-war technological "gap" with the US and to rapidly increase their share of the world market for various electronic devices. The government's industrial trade policies concentrated on setting technological targets, providing support for R & D, regulating foreign investment, and close monitoring of the use of licensed technology to ensure diffusion, and import controls. Moreover MITI has continually exhibited a remarkable capacity to collaborate with the private sector and to integrate their aims with those of the state. This climate allowed the private sector to pursue a well planned campaign to achieve technological parity plus aggressive marketing to maximise market penetration. (Dosi, 1981; OECD, 1980).

In the case of Europe, the history of government intervention also differs significantly from both the US and Japan. Here military involvement was very much lower and government intervention took place, until recently, on a less comprehensive scale and in a more ad hoc fashion. There were examples of extensive government support for R & D in particular parts of the industry in the 1960s and early 1970s (such as computers in the UK) but these rarely focussed on the semi-conductor sector. Nor were they at a high enough level or sustained over a long enough period to provide the necessary cushion for the private sector to achieve parity with the US. Hence there does appear to be a strong link between the relatively weaker overall position of the European electronics industry and the lack of government intervention - although obviously other factors are involved (see particularly Dosi 1981 on this point).

Perhaps more relevant to our interests is that European governments have since the mid 1970s, showed a renewed commitment to support the development of their electronics industry particularly as regards semi-conductors but also across a much broader spectrum of products and components. There are obvious reasons for the government's desire to involve themselves in the sector that are perhpas more obvious now than previously. Capturing a share of the lucrative and substantial world market for electronics products is no doubt important, but there are others. Perhaps most importantly there has been shown to be a clear link between the existance of a national capability in semi-conductor manufacture (including R & D and innovation) and the successful use of the technology in down stream industrial application. Drawing on the work of the Science Policy Research Unit in this area Dosi (1981) has argued that

> "the greater the geographical and economic distance between producers and end-users, the greater the difficulties in the free flow of knowledge, technician, scientists and technical information essential to the perception of new technical possibilities in downstream industries."
> (Dosi, 1981, p.20)

(See also Sciberras (1980), Sciberras, Swords-Isherwood and Senker (1978), MacLean and Rush (1978).

Clearly most European governments have accepted this argument. Table VIII shows that since 1975, 3 out of 4 major European countries have significantly increased their allocation of public money to support both semi-conductors and other sub sectors. Germany's allocation has dropped somewhat but this probably reflects the generally stronger presence of the private sector notably Siemens in the worldwide industry. In Europe Government participation has taken a variety of forms - from the establishment in the UK of a public enterprise (INMOS), for producing very large scale integrated circuits (VLSI) in direct competition with established producers in the US and Japan, to the support of joint ventures and mergers by the French (Matra/Harris and St. Goblain/PM/National Semi Conductors), UK (ICL and Fujitsu) and other governments; to a wide array of support programmes for the diffusion of microelectronics related products and processes in industry, commerce and for domestic uses (See EEC, 1981). For instance the UK has increased the amount of public expenditure on information technology (excluding support for research establishments and public purchasing) by £30 m in the last 10 months alone to a level that is over twice the amount spent last year (Hoffman and Miles 1981).

INSERT TABLE VIII

This shift towards more government support for electronics can also be detected in Japan and the US - though for different reasons. In 1979, Japan announced a major, publicly supported effort to further develop VLSI technology in the private sector. This project calls for a total expenditure of $360 m on R & D ($250 m direct government support) between 1979-1982 and follows on from an expenditure of 30 billion yen by the government during 1976-1979 for the same purpose. Since the Japanese have largely caught up with the Americans in many areas, this plan is a clear sign of a national intention to capture an even greater share of the future market for VLSI devices which are expected to replace LSI technology over the next decade. (Rosenberg and Steinmiller (1980).

The American government, for its part, has rejected recent requests from the industry for tax breaks on investment and trade barriers against Japanese imports. However, it does intend through the Department of Defense to spend some $190 billion within the US electronics industries over the next four years in a massive attempt to improve military technology (Connolly, 1981). This represents a significant increase over past years and is bound to influence the future development in funding of the commercial industry in many ways* since the military will want to be deeply involved in the setting of R & D and production priorities in order to ensure that it gets what it wants from the private sector.

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* One effect of possible significance for DCs is that there will be a tremendous call on the existing pool of US skills (software and hardware) to meet the military's requirements. The resulting gap in the commercial sector will exacerbate the already shortage ridden situation leading quite probably to massive attempts on the part of US firms to attract foreign "talent" - much of which is expected to come from the NICs. (Electronics, 1980).

In addition to the above military related programmes, various government agencies have been instrumentally involved in the further development of CAD/CAM technology and in achieving a standardised software language - which it is hoped will become the standard in the industry worldwide (with significant benefits accruing to the US industry through the sale of "packaged" systems) (see Kaplinsky, 1982).

We cannot here provide an assessment of the relative effectiveness of past DC government intervention in the electronics industry. However, there is a growing literature which suggests that whatever happened in the past, most AIC governments now recognise the cruical need to establish an efficient, technologically sophisticated electronics sector in order to secure a place in the emerging international microelectronics-based oligopoly which will dominate most of the major industrial sectors. (Dosi, 1981; Mackintosh, 1980; OECD, 1980). The returns to achieving effective participation in this oligopoly are enormous - both for companies and countries - and as we have argued extend far beyond the sale of electronics produced.

Hence, as governments and companies scramble to establish a competitive position in the cluster of inter-related industries called by the French, filiere microelectronique (semi-conductors, computers, peripherals, components, control systems, consumer electronics and information technologies) a number of be significant for DCs - some of which will be distinctly different from earlier periods. The trend towards sectoral concentration and firm level vertical integration in the major product lines will continue. The industry is already among the most concentrated in the world with no more than 6-10 firms accounting for the large majority of output in every major product line. (See Bessant, 1981; Bessant, Brawn and Mosely, 1980; Mackintosh, 1980; ETIU, 1979 for details). There are 3 elements in this trend which are worthy of note. The first, which has already mostly taken place, was the acquisition of semi-conductor producers by large established companies in other sectors. The wave of takeovers was quite dramatic, particularly between 1975 and 1979 when some 14 firms, many of whom were original innovators, were acquired by firms from Japan, Holland, Canada, UK and FRG. Secondly, a significant part of this takeover process has been the upward integration of established electronics-related companies in to semi-conductor production. (See Dosi, 1981 and Kaplinsky 1981, for examples). Thirdly, there has been a downstream expansion of semi-conductor firms into areas of application. This trend towards vertical and horizontal integration can be expected to continue and will increasingly feature both domestic and international mergers and joint ventures between AIC based companies.

Among the remaining competitors, there is now a much greater potential for bruising conflict and competition in the international market place. (Kaplinsky, 1982). Past struggles have resulted in significant changes in the character of the industry - the semi-conductor price wars in 1970-71 established American pre-eminance in the field, driving all but 5 European producers out of the mass market (where they were replaced in Europe by subsidiaries of US firms) and forcing them to operate at a loss in order to maintain their market position throughout the 1970s (Dosi, 1981). Now that the Europeans have recovered some of their strength (based at least partly on the takeovers listed above and government support mentioned earlier) and with the Japanese constantly increasing their market share and seemingly poised for an expansion of production operations into Europe, the stage seems set for another period of struggle among the titanics of the industry.

The a priori implication of these developments in the worldwide electronics industry for DCs are difficult to specify precisely at the present time. Through their control over technology and by virtue of shee size, established firms will be able to erect formidable barriers to entry for DCs hoping to break into the international markets for electronics products. These barriers may be overcome to a limited extent by NICs who already have an established technological capacity and are farsighted enough to already be implementing an electronics strategy based on exploiting very product specific comparative advantages.* (See Cable and Clarke, 1981).

At the same time, given the need for AIC producers to penetrate new markets to achieve scale economies, there may be fierce competition in DC markets for contracts to install telecommunication equipment, information systems, etc.** If skillfully exploited this situation of oligopolistic competition could allow the host country to achieve highly favourable terms. However, this is likely to be a difficult task for many DCs who lack the sort of sophisticated bargaining skills necessary to strike successful deals in high technology areas. Moreover, there are well established precedents of collusion between TNCs in other sectors as regards "competition" for contracts in DCs, such as was revealed by Newfarmer (1979) study of the heavy electrical equipment industry. This must at least be considered a possibility, particularly since many of the same firms mentioned by Newfarmer are involved in electronics and telecommunications. Nevertheless, there is as yet little evidence that such a trend is developing - so for the moment we can assume that competition rather than collusion will guide the actions of firms in DC markets.

Underlying both the moves toward integration and the emergence of fierce competition is the motor of technical change in process technology. This has led to rapidly rising fixed capital costs and the subsequent need to achieve even greater economies of scale through the use of increasingly automated production techniques. This trend could mean very major changes in an industry now

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* The Republic of Korea's planned expansion of its traditional electronics activities in the area of consumer electronics and component manufacture to achieve production valued at $4.7b and $3.0b worth of exports attest to their existing capabilities. Their future plans are to expand into semi-conductor manufacture via massive multi-million dollar investments in the Korean Institute of Electronics Technologies and through sophisticated joint ventures with foreign firms. This will allow them to custom produce ICs, pcbs and a variety of other process inputs as well as enhance its competitive position in areas such as consumer applications, small digital systems including micro and mini-computers and advanced colour TVs. The capabilities developed through these investments while not being "leading edge" should nevertheless ensure the Republic's continued strength in this area.

The Singapore Government has taken the decision to upgrade its software capabilities with an eye towards transferring itself into a regional software centre, with established international software houses operating in and sub-contracting to Singapore. To achieve this an extensive programme of education is being undertaken to develop the necessary skills. A generous programme of tax incentives to encourage Singaporean and foreign firms to expand their software activities is also being implemented.

** For some 13 NICs and nearly NICs Parthasarthi (1978) has shown that tele-communication equipment accounted for between 10 and 75% of total electronic imports in 1975. Between 1972-1980, the Asian countries alone planned investments of some $10 billion in the sector. These rates of expenditure are expected to continue well into the 1980s and 1990s.

characterised by an international division of labour in which exploitation of the cheap labour of the Third World has been an essential feature. In very simple terms, the logical extension of these trends is that the whole production cycle will now be located within the domestic economy of the AICs.

This is a very real possibility as regards the production of semi-conductors but may also become increasingly characteristic of other electronics products. The pace of development of automated assembly and automatic testing equipment in the semi-conductors sector is very rapid. As these are the only stages of the production process still located in off-shore assembly plants in DCs the implications are obvious. The same imperatives which lead the electronics industry to relocate part of its operations in low wage countries will in our opinion lead these firms to repatriate that production just as quickly once the technology is perfected and the trend established. (Hoffman and Rush, 1980). Unpublished research by Juan Rada of CEI shows that semi-conductor firms have located all of their new investment in IC production facilities within the OECD countries since the late 1970s. The following quote by the Group General Manager of ITT Semi Conductors shows the thinking of the industry was already oriented in this direction in the late 1970s.

> "A typical semiconductor company with a turnover of $200 million/year must expect today an annual price decrease factor of approximately $30 million, necessitating corresponding manufacturing cost reductions of $40 million. These cost reductions must result from increased mechanisation, higher yields and increased volume. A review of the relative advantages of increased mechanisation versus off-shore assembly comes down firmly in favour of the former, permitting closer customer contact, elimination of logistics problems, upgrading of local or national technology. ... the successful semi-conductor manufacturer must have complete production cycle in one manufacturing location." (Rada, 1980)

Similar technical developments are taking place in the technology for the assembly of final products such as TVs, radios, and home entertainment centres. The use of microelectronics has led to dramatic product changes, of which the most important has been the reduction of the number of components - in TVs the number has dropped from 1200 to 400 in a (standard) set (Sciberras, 1979). This, in turn, has facilitated the development of automatic insertion equipment which has the potential to perform assembly activities now performed manually (Senker, 1979).

Some automatic insertion is already being carried out by AIC based firms. There are however great differences in the extent to which the various firms are using automatic insertion and in the amount of R & D efforts now committed towards achieving full automation. Japanese firms are the furthest advanced in both areas reflecting the emphasis of their competitive strategy on reliability, efficiency and quality. All Japanese firms producing TVs adopt automatic insertion for component assembly - which accounts for over 75% of components inserted on printed circuit boards as well as automated testing procedures. US and European firms lag behind the use and development of automatic insertion for consumer electronics and appear content for the moment to continue to manually assemble in low wage countries (Sciberras, 1979).

However, automatic insertion is expected to become a major determinant of international competitiyeness in the 1980s, and given the past performance of the industry in rapid adoption of innovations, these technqiues should rapidly diffuse among firms in the industry. To be sure this is unlikely to lead in the short to medium term of complete cessation of DC assembly by TNCs no matter how extensively they may use automated equipment. For the time being the international market is growing quickly enough to accommodate products where DC assembly will retain its comparative advantage for exports to AICs. Growing domestic markets in the larger DCs will also encourage the international firms to maintain some production capabilities. However, in those sectors where DC exports are substantially controlled either directly or indirectly by international firms, the host economy must become increasingly susceptible to decisions by TNCs to pull out, change or down grade their product mix and/or reduce any innovative activities that might take place - these decisions will be increasingly influenced by the economic advantages afforded by automation.

This is not to say of course that the growing indigenous comparative advantage of some NICs in a wide variety of electronics products will necessarily be eroded. Certainly, these few countries - Hong Kong, Singapore, Taiwan, South Korea, and possibly Brazil - should be able to continue their success largely because of the technological base built up through collaboration with TNCs. No doubt these countries will continue to co-opt and account for an even larger share of Third World exports in this sector in the future. The real problems lie in wait for those other developing countries who have hopes that the expansion of recent TNC assembly into their economies (see UNIDO, 1981) will continue and will benefit their industrialisation efforts. This is unlikely. Even though the trend towards re-location of TNC electronics assembly inside AICs will take time to develop it seems inevitable. In the interim, it is unlikely that the TNCs who may have recently opened up assembly facilities in non-AIC free trade zones, would be willing to effect any real transfer of technology or stimulate linkages with local input suppliers on anything like the scale that took place in the NICs. As a result these countries will undoubtedly be able to maintain an export capability in later more standard electronics products which do not rely on leading edge IC technology. (Cable and Clark, 1981). Moreover, they will certainly benefit from any government supported efforts to build up an indigenous electronics capability to serve domestic requirements. However, the current oreinetation and the nature of the driving force behind international competition in the electronics sector will probably dictate that the sector is unlikely to provide the same level of stimulus for export-led industrialisation in these countries as it did in the NICs - a trend which certainly has important policy implications that will be explored in the final section.

Industrial Applications of Microelectronics

The size and evolving structure of the electronics sector clearly makes it a crucial element in the restructuring process and in the future development plans of some DCs. However, the downstream application of microelectronics industry is expected to have equal if not more profound effects in a wider range of countries. The rapid pace of change in the performance and cost characteristics of microelectronic devices has begun to be matched in the related areas of CAD/CAM *, robotics and sensing technology. This has lead to a high degree of concern in some quarters over the

* Computer aided design/computer aided manufacturing.

nature and scale of the potential impact of microelectronics related innovations (MRIs). Certainly in those areas where the use of micro-electronics is most advanced the concern is well founded - the rate and type of change in product and process technology has been particularly striking, as have been the resultant improvements in productivity. (See Bessant, Braun and Mosely, 1980; MacLean and Rush, 1979; ETUI, 1979, Forrester, 1981). Debate and speculation relating to these developments has often centered at the national level over the potential labour displacement effects of MRIs and, internationally, over the effect on a country's competitiveness of a failure to introduce MRIs quickly enough. (See Hines and Searle, 1979).

Two factors are important both to the resolution of the debate mentioned above and in determining the nature and scale of the impact of MRIs. The first is the capacity of a national economy to absorb labour displaced by the introduction of MRIs either in other sectors or through the job creating effects of output expansion that may arise precisely from the successful use of MRIs. These countervailing responses were largely responsible for eliminating earlier fears of massive job losses which were voiced in the 60's. While many observers continue to believe that a similar set of responses will take hold in relation to MRIs (Central Policy Review Staff, 1978) there are others who are less sanguine about the prospects and their forecast of long term structural unemployment have technical change as a principal determinant.

The second factor is the rate at which MRIs diffuse both nationally and internationally. Clearly, rapid diffusion of MRIs (and the accompanying changes in employment levels, industry structure, and comparative advantage) will have a different set of adjustment policy implications when compared with a slow rate of diffusion. This point is particularly relevant to developing countries since their ability to make effective adjustment to changing international economic conditions will depend at least in part on the rate at which these changes take place.

Obviously many factors will influence the behaviour of the above parameters. One of these, of course, is government intervention in the diffusion process. While the levels of AIC government involvement in stimulating diffusion has been less than in relation to the electronics sector per se, they have nevertheless been significant, and are almost certain to rise substantially in the near future. We have already discussed at some length the general shift towards more government support for diffusion. (See Table VIII). One specific example is the recently announced UK programme to invest £6 m in promoting the diffusion of CAD systems in industry (Large 1981). (See EEC, 1981; Hoffman and Miles, 1981; for other examples). Again the same caveats as before apply about the specific effect of government intervention on the rate of diffusion of MRIs in AICs. Nevertheless, there seems little doubt that despite the retarding effect of the current recession on demand there are growing signs that the rate of diffusion of process and product MRIs has continued to grow - from what is still, despite all the speculation, only a relatively small base. (See OECD, 1981; Hoffman and Rush , 1982). Under these conditions, government support unless badly misdirected can only enhance the rate of diffusion.

The significance for DCs of developments related to the use of MRIs in AICs has now been raised in a number of contexts (see Kaplinsky, 1981; UNIDO, 1981; Hoffman and Rush, 1980). Clearly there are many facits to the potential effects of MRIs on DCs - these relate to trade, employment, technological capabilities and skill availability, etc. While we must be careful about over-emphasising the potential effects - particularly on the poorer agriculturally oriented DCs - there can be little doubt that the issues raised by the diffusion of MRIs strike at the heart of the restructuring debate and its concerns with the changing pattern of DC manufactured exports and the creation of new, dynamic growth oriented industries in the AICs.

One of the principle concerns in both areas has been the likely impact of the widespread use of MRIs in AICs on DC comparative advantage in both traditional and non-traditional manufactured exports. In this case the fear is that the introduction of MRIs by AIC firms will eliminate many of the cost advantages currently enjoyed by DCs, leading thereby to a decline in their comparative advantage and calling a halt to the international division of labour which has so far benefited a few DCs. Although empirical evidence relating to this argument is still relatively rare, results are beginning to become available which both confirm and contradict this hypothesis and its underlying assumptions. Obviously given the very wide range of products and processes which DCs have begun to build up a capacity to compete internationally the issue of changing comparative advantage is not a straightforward one. Nevertheless we believe it is at least indicative of the nature of the changes being wrought by microelectronics that the studies reviewed below cover a broad range of products, processes and competitive conditions.

Kaplinsky's (1982) work for UNIDO on the impact of CAD on the international division of labour relates to the "leading edge" of MRIs and reveals a number of important developments. FIrstly, he shows that CAD systems confer a package of benefits to the user firms which make them an optimal choice of the technique, in both developed countries and in some NICs.* Second, a high rate of diffusion is expected in certain (high technology) sectors where DCs are hoping to specialise in the future and in which they have already enjoyed considerable export success - electrical machinery, electronic components such as printed circuit boards, office equipment, machinery, shipbuilding, etc. Thirdly, given the productivity enhancing effects of the technology (average around +3:1 in the firms interviewed), the use of CAD systems is expected to be an essential factor in allowing firms to remain internationally competitive not only in these sectors but in any sector where design and engineering skills are significant. Hence, in addition

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* The concept of a package of benefits is important. Much discussion of the impact of MRIs relates solely to effects on labour productivity. In fact all of the studies reviewed show that improved labour productivity is only one aspect of the benefits accruing to efficient MRI users - others relate to material and time saving, reduction in working capital, and systems level benefits which are much more difficult to measure.

to posing problems for the continued DC export success in the factors mentioned above,their recent well publicised achievements in winning international contracts, civil engineering works and process plant design andengineering (Lall, 1979), may well be short lived if Third World firms do not introduce the technology. Finally, despite the fact that it does apparently make economic sense for many DC firms to use CAD, the diffusion to the Third World has been disturbingly limited to date - out of the 6000 units which Kaplinksy was able to identify only 32 have been sold in developing countries. Such a low figure can obviously be explained. Nevertheless, the low level of utilisation and the other results do have important implications for the future policy of some DCs if they wish to continue to pursue export oriented industrialisation strategies.

Jacobssons (1980) work on the effect of microelectronics on the machine tool sector has also revealed a potential erosion in the still nascent DC comparative advantage in certain categories of machine production. The conclusions of this study are relevant not only to machine tools but to all machinery sectors in which the DCs, particularly the NICs have recently enjoyed rapid improvements in their export growth rate. He has looked at the capacity of certain DCs - namely Argentina, Brazil, Taiwan and South Korea to use and produce numerically controlled machine tools, particularly lathes. He shows clearly that the introduction of mciroelectronics - particularly related to the development of computer numerical control systems - has and will continue to have a significant impact not only on the technology on this itself but on the structure of the sector as well. One of these effects is that a very high degree of oligopolistic concentration has emerged in the production of less flexible, dedicated machine tool systems.* Here 3 firms, one Japanese, one German and one American through their technological leadership and due to scale related barriers to entry dominate the market to such an extent that the potential for any DCs to develop a significant share of the demand in AICs is very limited indeed. Secondly, the nature and level of benefits conferred by the use of CNC machine tools are such as to make conventional electro-mechanically controlled machines technically and economically inefficient. This means for instance in the particular case of DC firms already exporting machinery will lose their comparative advantage in the AICs unless they can switch to producing CNC lathes.

This is a switch which few firms now have the technical competence to make - (perhaps a few in Taiwan and one in Brazil). More to the point given the continuing rapid pace of technical change and the need to achieve scale economies in production this switch will be even more difficult for DC firms to make in the future. Although a sizeable market for conventional lathes obviously still exists within the DCs themselves, two factors militate against local firms being able to easily rely on this captive demand for much longer to build up their machine building capacities to the point where they can begin to design and produce CNC machinery. First, there is already a marked increase in demand for CNC machine tools in some NICs which is growing both in absolute terms and relative to total consumption of all machine tools. This is shown by Tables IV and X. This means that rate of growth of the local market for conventional machines is probably diminishing.* Secondly, there are signs that foreign suppliers, particularly Japanese may be ready to begin local production of machine tools for the South American market on a sizeable scale which could conceivably pose a threat to local producers (just as it does to European and American producers).**

INSERT TABLES IX AND X

It is still far too early to assess whether or not these developments pose an insurmountable barrier to the capacity of some DCs to produce CNC machine tools for export. Certainly one would expect that some firms in the more advanced NICs will be able to find a niche in the market for a particular type of special purpose lathe and exploit it. This possibility is confirmed by Jacobsson. But this is clearly not likely to be an automatic step for all DC machine tool firms - many do not have the capabilities to make the move nor are they supported by the

* The shift in demand towards CNC lathes obviously has other implications - the efficient use of these systems might help some firms to maintain their competitive position in the machinery production for export. A priori however, there is little one can say about the net effects of CNC lathes without further empirical information.

** In 1980, imported Japanese machines already accounted for 50% of US market NC lathes, 35% in the FRG and over 50% in France. The possibility that local production may be set up is a matter of major concern to their OECD partners (Done, 1982).

right sort of government policy vis a vis foreign investment and/or capital goods imports. Obviously we cannot easily extend the analogy to other categories of Third World machinery export. But nevertheless, the potential implications are clear - microelectronic based technical change in the machinery sector of AICs may pose a threat to the continued growth of DC machinery exports to AICs, particularly if we leave out the top few NICs (out of the sample) unless they develop an innovative capabilitiy based on the use of microelectronic devices.*

Finally, recent research by the author into the impact of MRIs on the clothing sector has also shown that there is a significant potential threat to some elements of traditional DC comparative advantage in this major export category (Hoffman and Rush, 1982). The pace of mechanisation in the clothing industry has been very slow for a variety of technical and structural reasons. The principle technical obstacle to mechanisation in the assembly phase of garment production has been the handling characteristics of the fabrics used. 80% of the sewing period is actually spent in fabric manipulation - picking up the pieces to be sewn, manoeuvering them into place under the needle, guiding them during the actual stitching movement, and then removing the completed item in this sector. "Limp" fabric is much more difficult to manipulate into position than a rigid material such as metal or plastic. In addition, fabric handling characteristics differ dramatically between different types of material meaning that any mechanised system must be able to handle all of these characteristics.

It is this factor, plus the degree of handling involved which has so far defeated numerous attempts to mechanise garment assembly. Efforts to overcome these technical obstacles have not been helped by the industry's reticence to devote on average less than .05% of sales towards R & D on equipment. In the face of these technical problems, the extremely low wages of assembly workers in the industry have allowed manufacturers to continue to substitute labour for capital to a much greater extent than is found in other industries.

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* Once again we need to insert some important qualifications. Though DCs are exporting machinery to AICs, a majority of exports go to other, particularly neighbouring DCs (Lall, 1979; OECD, 1979). This suggests the existence of a competitive but "appropriate" machine building capacity which may provide a valuable outlet for DC machinery export should AIC markets become more difficult to penetrate.

Due to the slow rate of technical change in the past there are only marginal differences in the use of techniques between DCs and AICs. Given this situation, the cost advantage of low wage producers in the DCs will remain a dominant factor determining the international division of labour for the next few years at least. However, a number of variables in the equation and their relationship to each other are beginning to change substantially. One of these is technical change and is largely due to the slow but inexorable advance of microelectronics through the industry.

MRIs are now being introduced at every stage of the manufacturing process, albeit still in small numbers relative to the size of the industry (Hoffman and Rush, 1982). The number of capital goods manufacturers of microelectronics-based equipment has risen dramatically over the past few years from 4 to over 30. A number of the new capital goods firms in fact have a background in electronics rather than the mechanical engineering focus of traditional producers.

The most significant innovations have been introduced into the pre-assembly phase which includes design, resting, pattern placement and cutting. These activities, traditionally highly skilled and largely manual have now been replaced by the use of state of the art CAD and CNC technology. The cost of these systems ranges upward from $300,000 - quite a change for an industry used to spending only hundreds of dollars for its capital goods in the past. The use of the technology has completely altered the nature of the activities carried out at this stage and require systematic changes in the organisation of production to capture the full benefits of the innovation.

In the assembly phase, the scale of change has not been nearly as great as described above. Here the sewing machine, operated by a single worker remains the main production tool. For the most part, the MRIs in use at present could be termed incremental innovations (Hoffman and Rush, 1980).

Some of these are first generation innovations - where what were previously electromechanical control systems attached to and guiding the sewing machine have now been replaced by dedicated microprocessor based systems. The electronic capacities of these systems are relatively crude compared to the advances evident in other sectors, but nevertheless their increasingly widespread acceptance represents an important first step for an industry which is notoriously conservative.

Taken together these innovations in the pre-assembly and assembly stage confer significant benefits in the areas of material saving, increased labour productivity, reduced turnaround time and working capital requirements and certain other systems - level improvements. Their use by AIC manufacturers has led in one or two cases, to the domestic production of garments which previously would have been carried out in a low wage economy. To be sure this does not represent a major shift in comparative advantage in favour of the AICs across the board the lower unit production costs in the DCs still favour them in many products. However, in our opinion, these developments are clearly the harbinger of a trend in certain sub sectors of the garment industry which could become more dominant in the absence of any counterveiling responses by the DCs.

Technical change in the garment industry is taking place in the context of developments in other areas which will be important determinants of the rate of diffusion of MRIs and the impact of these on developing countries. A brief look at some of these factors will illuminate the related arguments made at the beginning of this section.

The first of these is an increasing interest by AIC governments in supporting basic R & D work to overcome some of the major technical difficulties that stand in the way of achieving a greater degree of mechanisation and capital intensity. The US, EEC and Japan have all recently begun to provide (varying degrees) of support for this work. As yet the amounts being invested are not great though there are indications that support will be increased substantially in the near future. These measures do represent an important shif in the government approach to this sector which had previously not involved a substantial commitment to support R & D.

The second development is that the clothing industry is undergoing fundamental structural changes both within AICs and in the international structure of the industry. Traditionally, the industry has been highly disaggregated with a very large number of small to medium sized firms and only a relatively few large firms.* This is all changing as a rapid process of concentration and agglomeration takes place. The large bulk

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* The overall average size of firms is much smaller than is normal in manufacturing industries. Firms of 50 workers or less dominate certain parts of the industry, while over 200 workers is considered to be a large firm.

of medium sized firms are disappearing or being taken over by larger firms. For instance in the US the number of firms declined from 22,000 to 14,000 between 1972 and 1977 a number expected to be less than 10,000 by 1985. Industry observers confidently predict that within 10 years the dominant structural characteristics of the industry will be oligopolistic competition between few very large, vertically integrated firms operating at an international level and numerous very small firms able to respond quickly to the rapid changes in fashion characteristic of part of the industry's products. The significance of this concentration is that the larger firms will be in a much better position to be able to (a) afford the considerably more costly process innovation which are likely to become available in the future and (b) have the resources, expertise and longer term view necessary to support the large amount of basic R & D still required to achieve technical breakthroughs.

The third development has actually been evident for some time - a continual rise in the average levels ofprotection and trade regulation measures adopted by a number of AICs. Despite the successive rounds of trade liberalisation organised under the auspices of GATT over the last 20 years, individual importing AICs, have continually had recourse to "special case" clauses which have permitted these countries to effectively discriminate against particularly problematic categories of DC imports.

In textiles and garments, these measures began to be applied in ernest in 1962 when the first LTA was negotiated. Since 1973, internal economic pressures within the AICs have lead to renewed pressures to again increase tariff and non-tariff barriers. These culminated in the passage of a revised MFA agreement in 1976 which had an immediate and drastic effect on the rate of growth of DC exports of textiles and garments. Some DCs, particularly the top 3 NICs - have managed to increase the unit value of their exports to AICs since 1976. However, more importantly there has been very little overall growth in the volume of Third World exports - in 1977 there was no increase in volume, in 1978 volume increased only by 8%, and in the 1979-81 period growth increases in volume again slipped back to near zero. (Keesing and Wolf, 1980).

Overall, the Third World share of (very slowly growing) world trade in garments has remained stationary at 37% since 1977. The much heralded increase in Third World clothing exports has been brought to nearly a screeching halt since 1977.

These reductions in growth rates have largely been due to the retarding effect of the second MFA and the bilateral agreements negotiated subsequently between AICs and major exports. In addition to reducing the growth of Third World exports, the trade barriers have introduced other distortions into the system. During the latter half of the 1970s it is true that new DC exporters emerged, frequently increasing their exports of particular garments at a phenomenal rate.* However, by and large these new and cheap sources of supply were brought into the international division of labour as a direct result of tariff and quota jumping activities by international firms or by a few large enterprises in the big three. The direct benefits to the host DCs involved in this (still) relatively small amount of managed trade must inevitably be very small since transfer pricing is frequently involved.

More important, it is not at all clear that the leading NIC exporters, South Korea, Singapore and Hong Kong, who together account for some 75% of all Third World clothing exports, will easily relinquish their dominant position in the markets which have changed little since 1977. All these countries have recently announced plans to upgrade and expand their clothing production capacity and although they locally support the efforts of their poorer colleagues there is no sign that they are prepared to step aside and make room for the newcomers. (Hoffman and Rush, 1982).

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* For instance Indonesia increased its exports of jeans to the UK from only a few 1000 pairs in 1977 to over a million in 1981.

These developments offer little solace to non-NIC DCs who are still counting on a rapid expansion of clothing and textile exports to provide an impetus to the industrialization plans - playing much the same role they fulfilled during the earlier industrialisation phase of the NICs. The "success" of the second MFA (which expires at the end of 1981) combined with the continuing competitive strengths of the NICs has meant that many countries are still waiting for this take-off to take place.

Prospects for the future could hardly be less encouraging. The EEC which rapidly emerged as the major growth market for DC clothing exports in the 1970s has approached the ongoing MFA renewal negotiations from a seemingly intranscient protectionist position. Hence the outcome of these vital negotiations is still in the balance - though some observers believe that the Group B proposals for a third MFA are little better than no agreement at all.
Certainly there is precious little room in any imaginable compromise under the current stale mate which holds out the prospects of a guaranteed steady increase in the share of AIC clothing imports going to the poorer DC exporters.

Two features stand out about past and current attempts to increase the level of protection accorded to AIC domestic garment producers. First, AIC producers have long argued that the precipitous decline in the fortunes of their industry (particularly employment losses) has been largely due to the pressure of cheap imports from low wage countries. However, a number of studies have now shown that although import penetration is quite high in some specific products in certain countries, the demise of large portions of the clothing industry has been due to improvements in labour productivity, competition from other AICs and the international subcontracting activities of domestic firms. (Shepherd, 1980; Field, 1976; Cable, 1979). A typical example can be drawn from Cable (1979) which shows that although West Germany did experience a high rate of growth of DC imports these had only a negligible impact on labour displacement. For the period 1962-1975 the numbers and causes of job loss are as follows:

Table XI Jobs Lost in West German Clothing Industry 1962-1975

Reasons for Job Displacement	Numbers
Improvements in Labour Productivity	6,500,000
Growth of all Imports	1,200,000
Growth of Imports from DCs	133,000

Source: Cable (1979)

The example shows that the imposition of the MFA and other restrictive measures have had little or no empirical justification. To be sure, there are certainly grounds for arguing that the existing pool of DC exports should be shared out more equally - thereby giving the poorer countries some of the growth opportunities previously denied them. However, the manner in which protection is currently being administered (and the EECs proposals for the future) leave little scope for this to be accomplished.

Secondly, it is important to note that the long and painful struggle over the regulation of clothing and textile exports has taken place in the very first sector where developing countries have begun to establish an independent competitive base of any substance. The difficulties encountered so far are a disturbing precedent for the restructuring process particularly if this is meant to be a process whereby the AICs are expected to relinquish their dominant role in an increasing number of sectors to an increasing number of developing countries. Future prospects for the smooth conduct of restructuring negotiations are all the more worrying since it is clear that what Helleiner terms the new wave of industrial protection is, as we shall see, being increasingly extended to a much wider range of sectors such as footwear, transport equipment, steel, household appliances and many others (Helleiner 1979).

This discussion of various aspects of the impact of MRIs has tried to bring out the relationship between technical change, AIC innovation policy and the other contextual elements mentioned earlier. Before concluding the section we would like to briefly discuss another much more explicit example of how these elements can combine to pose direct and immediate problems for DC policy makers of a different sort to those discussed above.

Technical change and innovation policies for renewable energy technologies: A direct assault on the third world

A decade of rising prices and growing awareness of the scarcity of conventional fossil fuels has generated a massive surge of interest worldwide in the potential of renewable sources of energy to help solve the energy crisis. Though the level of R & D and manufacturing activity in the sector is still small relative to the conventional energy sector, it is already substantial and growing rapidly since these sources are expected to provide a major part of energy supply in the future restructured world economy. Moreover, as with electronics the coalition of elements we have been stressing so far are all present in current efforts to develop suitable renewable energy-based conversion and transmission systems: rapid technical change, substantial government support for innovation and diffusion, extensive involvement of large international firms; and perhaps unlike the electronics example these activities have an immediate and direct relevance for the Third World.*

Developing countries hold out great hopes for the use of renewable energy technologies (RETs). This is because the configuration of characteristics usually attributed to RETs match well with their resource endowments and energy needs - particularly in the rural areas. The

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* This section draws extensively on research by the author. See Hoffman, 1980 and Hoffman, 1982 for a more detailed discussion.

energy sources - direct sunlight, biomass, wind, water, etc. are available in great abundance and the required conversion systems are potentially inexpensive, relatively small-scale, and simple to construct, operate and maintain. Hence, a great deal of momentum is building up for DCs and international agencies to commit large scale resources to the development and introduction of RETs. One sign of the future importance of this area is the effort and attention shown by many countries to the recent UN conference on New and Renewable sources of Energy held in Nairobi in August 1981.

AICs also see great potential in RETs. However, since the technologies are still in their early stages of development, a great deal of investment in R & D is still rquired to bring the system close to commercial fruition within the AIC context. Hence public sector investments in R & D and diffusion already massively dwarf similar efforts in the Third World. Table X gives details of government investments in RET R, D & D in 1979 for 17 countries and the EEC. This support has been increasing rapidly over the last five years. Table XI shows the average rate of increase in RET R & D spending between 1978-79 for all 17 countries covered by the International Energy Agency.

INSERT TABLE XII AND TABLE XIII

While it is unlikely that AIC public sector support for R, D and D will continue to rise at such high rates in the future - particularly as the base totals get bigger - there is a widespread expectation that private sector spending will expand to take over that role. This is a trend which is certainly developing in some segments of the sector. The long term objective of these public sector activities is to promote the domestic use of RETs on a major scale in order to lessen dependence on conventional fuels. Central to their strategies is the development of a viable private sector to manufacture and stimulate demand within the domestic economy and the development of a viable private sector industry capable of providing the necessary systems and back up support.

At the moment, however, relative prices do not yet favour the widespread use of RETs within AICs. Hence a very high element of risk is involved which in the absence of government intervention would lead to sub-optimal investment by the private sector and since the investment of time and resources necessary to achieve certain technical breakthroughs and bring the systems to commercial viability is still considerable. One way AIC governments are reducing this risk is to provide financial support for R & D and other development related activities within the private sector. Consequently, much of the money allocated by government (as shown in Table X) goes to private sector initiatives. (See Hoffman, 1982 for details).

Another means of reducing risk is to cultivate overseas export markets. There is a near uniform opinion on the part of AIC agencies that the DCs already offer one of the largest markets for RET exports, particularly in the rural areas where the isolated population have to depend on expensive energy sources with which some RETs are already competitive. The early exploitation of DC markets is considered to be an essential stage in the expansion of the domestic industry, allowing it to accumulate experience, build up capacity, and reduce prices in order to open up the longer term but more sizeable markets within the AICs. This strategy is enshrined in virtually every policy statement emanating from the public sector in the AICs and the EEC. (See Hoffman, 1982).

To this end AICs, particularly the US, France and W. Germany, have mounted a variety of programmes designed to promote exports to DCs which include export subsidieis, bilateral aid initiatives, trade shows and tours to generate orders, investment credits, etc.

The private sector in most AICs for its part has very quickly seen the potential and taken advantage of government centres to build up a quite significant R & D and manufacturing capability. Most attention and investment has gone into the development and diffusion of photovoltaics and industrial scale biomass to energy technologies.* Three trends in private sector activity in these technologies are significant.

* Photovoltaic cells which need little maintenance and are extremely durable convert sunlight directly into electrical energy. The cells, made from the same material used in the production of integrated circuits are produced in module form and can be combined to give output ranging from less than a kilowatt to multi megawatts. Biomass-energy technologies involve the conversion of almost any organic matter into a liquid of gaseous fuel which can replace fossil fuels.

Firstly, in both sub-sectors, concentration is taking place very quickly with large, well-established, international firms moving to establish an R & D and manufacturing capacity which will allow them to dominate both the national and international market in the future.

In photovoltaics, US firms dominate and among these almost all of the small innovative companies which were instrumental in earlier periods have succumbed to losses or to takeover bids from large energy or electronics related companies such as Amoco, Exxon, ARCO, Gulf, Mobil, Texas Instruments, Boeing, Motorala, Westinghouse and RCA. In Europe and Japan, large international firms have always dominated: Siemens, Lucas, CFP, ELF Acquitane, Phillips, Toshiba, Toyota, Mitsubishi, Fuji Electric - and are in fierce competition with US firms for a share of an annual world market which could be well into the billions of dollars by the 1990s.

In biomass to energy technologies, international firms, many with extensive Third World links, are also achieving dominance. These come from a variety of sectors - Industrial Enzyme and Chemical producers - (Bayer (FRG), Pfinzer (USA), Rohm and Haas (USA), Dow Chemical (USA) W. R. Grace (USA); engineering firms - UHDE GmbH (FRG), W. G. Atkins (UK), Constructors John Brown (UK), Lummus and Kellogs (USA); food and sugar manufacturers - Tate and Lyle (UK), Bookar McConnell (UK), Grand Met (UK); and most of the oil majors.

Secondly, these firms are themselves investing heavily in R & D with an eye towards developing an innovative capability which will be essential in maintaining their competitive position - a rough guesstimate is that over the next 2-3 years the top 20 firms in the photovoltaics industry will invest in the region of $350-400 m in R & D, pilot production, and some expansion of existing capacity. In support of these efforts the US government plans to spend about $1.5 billion between 1979-1988 on various aspects of photovoltaics R, D and D in the private sector; the French spent $21 m. in procurement and R & D in 1979 - a figure expected to increase; and the West German government spent some $34 m in 1980 alone. It is not possible to provide estimates of private sector R & D in the biomass-energy area but anecdotal information reported in Hoffman, 1982 shows that it too is significantly above the $50 m per year level. Public sector support is smaller than in photovoltaics but is also expected to grow rapidly.

Thirdly, as mentioned above the rapid exploitation of Third World markets is an essential part of the commercialisation strategies of firms in both sectors, albeit with differing rationale. In photovolatics, economies of scale are a crucial factor in achieving the reduction in unit costs potentially attainable with current and future cell fabrication technologies. The steady reduction in unit costs are in turn essential to opening up a succession of ever larger markets - with penetration of domestic and industrial AIC markets as the ultimate objective. This process, similar to what occurred with semi-conductors, is still in its early stages with sales of photovoltaic cells concentrated in high cost specialised uses such as powering remote communications networks. To achieve the next stage in cost reduction, larger quantities need to be sold and DC markets are the prime candidates.* Exploitation of these markets within the next 10 years is crucial if AIC producers are to achieve the scale economies necessary for them to be competitive (with the unit costs of conventionally supplied energy) in AIC markets in the 1990s.

DC markets are appealing to biomass-energy firms for a different reason. Rather than marketing the final product as is the case with photovoltaics, AIC firms are keen to sell or license process technology - for all the usual reasons well documented elsewhere. Generalised energy problems, abundant raw material supplies and the success of Brazil** have

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* The lack of effective purchasing power by the rural poor - who are the primary target group to use photovoltaic systems does not seem to yet bother the AIC producers. A dominant theme in the private sector reasoning is that aid funds will be used initially to purchase cells for use in rural areas with the country's themselves stepping in later on with their own resources. This rationale has some major flaws in it. (See Hoffman, 1982).

** Brazil has embarked on an ambitious and so far successful programme to reduce its dependence on imported fossil fuel by converting sugar cane and cassava to ethanol. Since 1975 the country has invested on average $200 m a year to build over 200 ethanol refineries which displaced about 20% of their petroleum requirements.

already stimulated a good deal of interest on the part of many DCs - thereby creating a ready market for AIC technology suppliers. AIC producers, many of them still of great potential in the process of developing a technological capability in this area, can learn a great deal from constructing and operating what are in effect pilot plants in developing countries. The possibility of using Third World sales as learning vehicles is made all the more attractive if risk capital is provided by the country itself or some other source of external funds such as the World Bank (See World Bank, 1980). This is expected to happen on an increasing scale as the World Bank and other agencies have shown a strong willingness to support industrial scale biomass-energy projects.

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The developments outlined above highlight a number of issues relevant to our interests. The fact that AIC firms are carrying out extensive, publicly supported R & D commercialisation activities is not per se a reason for concern. The concerted application of AIC know how in the area would advance the technology very quickly - a priori this can only be a positive development in welfare terms. The problems lie rather with the degree of concentration of RET innovative activities within private sector firms based in the AICs. This concetration, which obviously parallels what is happening in electronics and other sectors, means that the innovating firms are very well placed to effectively appropriate much of the basic technical knowledge in the RET area. (See Cooper and Hoffman, 1982 for a discussion of appropriation). In addition, the firms are quickly expanding into the wide range of activities necessary to successfully commercialise their innovations domestically and internationally by developing applied capabilities to design and engineer products to suit differing conditions, to manufacture RET-specific capital goods to carry out the installation, operation and on site maintenance and modification of the systems themselves, and finally to undertake the marketing and distribution activities necessary to exploit a growing market.

Hence these firms are developing a set of technological capabilities which will first establish their position as leading innovators and second, leave them very well placed to usurp opportunities that open up in the developing countries and elsewhere. Needless to say their position is considerably enhanced by the fact they are extensively supported by their own governments and because of all this activity is taking place in a climate which favours the investment of resources in introducing anyway RETs into developing countries.

The implication of these trends for developing countries are fairly clear. A state of technological dependency is being created in a sector of considerable importance in the future. DCs seeking to acquire RETs would therefore face a situation with all of the characteristics usually attendant in other sectors where they are technologically dependent - the usual difficulties associated with inappropriate products and processes, the short-run costs resulting from the extraction of monopoly rents by supplier firms, the longer-term social cost resulting from the denial of learning opportunities to local firms, etc.

The important point in all of this from a policy point of view is that as yet these trends are only <u>beginning</u> to develop. Hence there are still significant opportunities for DCs to take steps to prevent the trends becoming a structural reality. For some time yet DCs will be in a strong bargaining position vis a vis their power over allowing access to local markets. This could be used to ensure that technology transfer takes place in such a way that the necessary technical skills are accumulated under their control rather than those of the AIC firm. This, plus the fact that the technology is still quite flexible, in turn could lead to the development of more appropriate technical solutions in the longer term. To achieve this there is a clear need for DCs to formulate and implement a strategy vis a vis technology transfer and innovation that takes account of how all the elements described above interact with each other.

While the conditions in this sector are clearly different from those that exist in electronics or other sectors, they do underlie the more general arguments being made about the role of technical change and AIC innovation policies in the restructuring process, and the facilitating effect of other factors in creating a new set of conditions that will have to be faced by DC policy makers. In the final sections we move on to consider the implication of these trends and new conditions for DC industrialisation strategies in the future.

SECTION 1V THIRD WORLD RESPONSES: SOME CONTEXTUAL CONSIDERATIONS

In the preceding discussion we have concentrated most of our attention on various developments which have been taking place largely within the advanced industrial economies. The general thrust of our argument has been that as a result of these developments, developing countries face an international economic and trading enviroment in the 1980s that is very different from earlier periods. We have emphasised two factors as being important determinants of these future conditions - the dismal economic performance of the AICs in the 1970s (and their poor prospects for the immediate future), and the increasingly important role of technical change as a factor in international competition and in the restructuring process.

Poor economic performance in the AICs has several implications for Third World export oriented strategies. Due to the generally depressed nature of demand and slow output growth, DCs can no longer rely on gaining easy access to guaranteed markets in the AICs. Competition for export markets will inevitably become more severe and the weaker competitors, including many of the poorer DCs, will suffer accordingly. Historically there have always been persistent pressures for tariff protection against imports of low-cost traditional manufactures from DCs. These problems have been exacerbated by rising unemployment in these sectors. The structural nature of the current unemployment situation suggests that it will be a problem for some time to come - and hence the resultant protectionist pressures will also remain in place.

Moreover, as a result of a more general trend of rising unemployment and over capacity, these pressures are also increasingly being directed at DC exports from other non-traditional secors resulting in a sharp rise in the use of non-tariff barriers (NTB's) to trade.* Though these NTB's clearly pose a problem for these NICs who are now heavily dependent on manufactured exports to sustain their high rate of growth it is the case that the most distorting effect of this sort of protection often falls on those poorer DCs who are least able to retaliate (Helleiner, 1979).

The significance of the technical change factor in our argument rests on two trends. Competitiveness in international markets for products at all levels of complexity will be increasingly based on technological factors. This trend will be enhanced by the diffusion of microelectronics which may cause shifts in comparative advantage against slow adopters and will also lead to changing patterns of international investment. Previous DC export strategies based on low wages and the accumulation of conventional technological capabilities may be partly at risk. A new element in this is aggressive AICinnovation

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* UNIDO (1981) has emphasised the rising tide of neo-protectionist measures in use by AICs against DC exports of steel, chemicals and engineering products. These measures are also being used against imports of electonics products where some NICs have been able to build up an internationally competitive technological capacity. The best known recent example relates to the efforts of South Korean TV firms to export to Western European and US markets. The Korean firms had to acquire a license to produce TVs with the transmission system suitable for use in Western Europe, Phased Alternating Line (PAL). They required a license for marketing purposes and not to gain access to the technology which they already had. However, they were unable to acquire the licenses and were effectively excluded from the European market, because of the Europeans' fear of competition. (Scibberas, 1979).

The only alternative was to actually produce in Europe, a strategy that has been successfully followed by the Japanese. The South Korean firms were unable to do this because they lack the "expertise, capital or market share to enable production location in Europe to offset PAL license constraints" (Sciberras, 1980). A similar situation has been reported in the US, to which South Korean firms attempted to promote TV exports and were excluded, not by lack of access to licenses this time, but by tariff barriers. Once again, as in the European case, the Japanese strategy was to locate production the US. As a result of the South Korean firms being unable to do this, their Korean based plants are currently operating at only 21% of capacity (Hanson, 1979).

policies designed to ensure their position in the emerging international oligopoly based on the new technologies. Taken together these factors will lead to increased concentration, new barriers to entry, greater opportunities for collusion and equally costly bouts of competitions between national capital. (See Murray, 1972 for an early statement of these arguments).

The overall impact of these changes has been, in effect, to alter the "rules of the game" that have so far determined the nature of the international division of labour on which many developing countries have been integrated into the world economy. For those countries who have not already achieved a sufficiently high level of export diversification and technological sophistication the capacity of the 70s strategies for achieving export led growth in the future on the basis of low wages and the accumulation of conventional electro-mechanical/engineering capabilities must now be placed in doubt. The escalator of rising export growth, increasing value added, and favourable comparative advantage which a number of DCs have been riding towards NIC status appears to be slowing down dramatically. The steps at the bottom of the escalator are increasingly crowded by those DCs who believe they can take the same route as their predecessors. Moreover, the motor of rising output growth in the AICs no longer seems able to cope with the added weight, while the AIC reception committee waiting at the top is certainly not quite so keen to admit more members to their club.

In order to be able to give a policy interpretation to this changed perception of DC prospects we need first to explore in a little more detail the nature of their past efforts and the principal characteristics of DC economic performance over the last 15 years or so. A number of features stand out. The first is the rapid rate of increase in Third World exports of manufactures. Their performance over the period between 1965-1977 has attracted the most attention. Overall, Third World exports increased by around 26% during this time (Lall, 1979, 1980), with individual countries recording even higher rates of growth. A number of countries participated in this expansion - by 1975 over 40 DCs were able to export manufactures valued at over $100m. Though exports of clothing, textiles and leather goods were very dominant * DCs were able to move beyond a reliance on traditional products and achieve quite sizeable increases in their exports in other sectors, such as wood products, miscellaneous manufactures, rubber, metal and non metallic mineral manufactures, iron and steel, chemicals, transport equipment, non-electrical machinery and paper products.

This performance is unquestionably a significant achievement - particularly when it is balanced against some of the more pessimistic forecasts found in the development literature of the early 1970s (Sunkel 1969; Little, Scitovsky and Scott, 1970). Even more significant is the fact that only 12 countries * accounted for nearly 80% of total manufactured exports from the Third World over this period.

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* For the NICs, these account for over 40% of manufactured exports from South Korea, Taiwan, Hong Kong and Singapore, and over 20% from Brazil, Argentina and Mexico. For the less industrialised countries, the percentages are even more dramatic, accounting for 73% of manufacturing exports in Egypt, 79% in Pakistan, 52% in India, 97% in Bangladesh, 71%in Iran and 61% in Morocco (Kaplinsky, 1981).

This unprecedented expansion of NIC exports (and with it significant increases in national income) has many aspects to it. The apparent success of these relatively few countries in pursuit of an export-oriented industrialisation strategy has led many to attempt to take similar steps - often at the insistence of advisers in international institutions (See Hughes, 1980).

The dominant presence of the NICs in Third World manufactured exports is mirrored in many other categories - share of value-added in manufacturing, contribution of industry to GNP, diversity of the industrial base and degree of backward linkages, and the level of technological development, etc. (See OECD, 1980). While this pattern of extreme concentration is undoubtedly a sign of success it is also a measure of how relatively poorly the rest of the Third World is doing in their industrialisation efforts - particularly if it is remembered that since 1977 the share of the NICs in all of these categories vis a vis the rest of the DCs has rarely declined substantially (e.g. the example of clothing export given earlier). Hence, the pattern suggests that the NICs have achieved a level of economic strength and technological development (and face a range of problems) that not only are dramatically different from that achieved by other DCs . This is partly because of the different economic circumstances which pertained; and partly because the NICs enjoy a different relationship to certain aspects of the world economy than that of other DCs. It may be useful to highlight two aspects of these differences which we feel will be crucial determinants of the response capacity of both NICs and non NICs.

The Role of Transnationals

One obvious difference in circumstances has already been mentioned - the higher rates of growth enjoyed by the AICs until 1970. A particularly important factor associated with this earlier period of growth and accumulation was the rise of the transnational corporation and the global expansion of its activities. Developing countries, particularly the NICs were initially brought into the world economy largely on the terms dictated by international firms who were seeking, by and large, to minimise global production costs by locating some or all the production phase in areas characterised by low wages, favourable incentives, stability - (i.e. strong central control and few workers rights) etc., extensive both in aggregate terms (e.g. foreign firms now account for 46% of industrial sales in Peru; 49% in Brazil, 31% in Argentina, etc) and,more importantly, in respect of their dominance of specific sectors - particularly the most dynamic and fastest growing areas of consumers and producer goods (Newfarmer, 1980).

Although some observers have argued that there is insufficient evidence to point conclusively to a correlation of TNC activities in export-oriented sectors (Lall, 1979), there is data that indicates that TNC participation is relatively high in those sectors that have recently experienced the highest rates of export growth. Most notable among these is the electronics sector where the combined value of exports by wholly owned subsidiaries and joint ventures was equal to 70% of total electronics exports from South Korea (1975), 99% from Singapore (1975) and over 90% from Argentina (1979) (Parthasarathi, 1978; ESCAP, 1979). High concentrations are reported in engineering sectors as well. Lall (1979) argues that TNCs contributed over 55% of engineering exports in Brazil, Mexico and South Korea. Hence, in addition to acknowledging the impressive increase in manufactured exports from the NICs, we must also recognise that this growth was extensively managed by AIC firms and their affiliates in the NICs.

The evidence concerning the tendency for TNCs to be particularly active in manufactured exports from the NICs is underlined by the role played by international corporations in world trade in manufactured products * (Helleiner (1977)). One estimate is that approximately one third of world trade takes place between TNC parent firms, subsidiaries and affiliates (Murray, 1979). Having such a significant share of world trade, escaping the market, as it were, and being managed on an intra firm basis by internationally based corporations clearly poses many problems for both DC and AIC governments.

Many observers are quick to point out that the largest share of DC manufactured exports - garments and textile - are sectors where TNCs are notable by their absence. This is true as far as it goes - however there are "compensating" factors that must also be acknowledged. Firstly, exports of clothing and textiles, while mostly produced by independent DC firms are very tightly tied to the actions of importers and retailers based in the AICs who provide the means of gaining all important access to the final consumer. The scale and nature of DC production (e.g. product style, quantities, production schedule etc), is very heavily dictated by these intermediaries who can, and do, shift their allegiance very rapidly from one supplier to the other if the "price" is not right. Secondly, as we showed above, a rising share of this trade is being "managed" by TNCs with the assistance of off shore tariff provisions. Thirdly, the level of concentration and the share of the market is increasing among these firms who, in turn, operate the typical international package of overseas affiliates in DCs with the typical implications for the host country.

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* Trade in primary commodities is subject to exceedingly high levels of control by international corporations and their affiliates. The proportion of US import of major primary commodities which are from US TNC affiliates or related parties rarely falls below 70% and frequently exceeds 90% (Helleiner, 1977).

There are many facets to the debate over the net impact of foreign control over manufacturing activities in developing countries which are widely discussed elsewhere . Significant among these is the fact that control of production unit by TNCs means that a substantial degree of national control over economic decision making is instead transferred abroad as a result - "host countries have lost important elements of control over their economic destiny." (Newfarmer, 1981, p.13).

This loss of control and decision making by the national government is obviously a real problem in light of our earlier emphasis on the changing nature of international competition. TNCs take decisions on production, location, new and expansive investment, market destination, product mix etc. in response to global rather than national factors. If the conditions which earlier led them to establish low value-added assembly-type operations in DCs change significantly, as we suggest they may be doing, the host country planners are left susceptible to the vagaries of TNC management decisions. The potential costs of not being able to control or at least influence these decisions is obviously compounded if the sectors at risk are export-oriented and act as growth poles for the domestic economy. Clearly the scale of any disruption that arises will vary greatly from sector to sector and country to country (Newfarmer, 1980 gives many examples of the exercise of TNC power in this regard) - with the poorer DCs being commensurately more vulnerable - and at the same time more dependent on the actions of foreign firms. In view of the changes that are occurring in the world economy, one can imagine any number of shifts in TNC strategy which could substantially alter the capacity of NICs (and all DCs) to continue with their present plans to build up (and maintain) an export capability. Many of these actions - ranging from total relocation of production facilities, rationalisation, down grading of the product mix to less sophisticated products, a reduced degree of technology transfer and/or declining levels of technical change activities - have already been taken by TNCs in response to changed conditions in the global economy (See earlier discussion, and Rada, 1980; UNIDO, 1979; Newfarmer 1979; Hoffman, 1980).

The policy problems in this situation lie not only in trying to anticipate the nature of these decisions but also in devising effective responses in order to minimize their effect. Beyond that is the clear need for policy makers to take steps to reassert control - this however is a difficult step to take particularly if the current activities of the TNCs provide crucial foreign exchange earnings. Nevertheless, the degree of long term uncertainties created by current TNC participation in export sectors should not be overemphasised. These uncertainties can be reduced by government action. However, responsibility for the fact that TNCs enjoy such a dominant position in many national economies lies in the end with the government. Either by choice or through mismanagement the short term interests of many DC governments identified very closely with those of their foreign guests. As has often been suggested, this is a relationship which weakens the DCs bargaining position and reduces the flow of benefits to the country as a whole without necessarily impoverishing the groups in power. Hence, any improvement in the situation will only come through concerted action on the part of the government - a step which many govenments have shown themselves unwilling or unable to take.

The Role of the Energy Factor

Perhaps the single most pervasive change in circumstances facing non-NICs that was not present during the NICs early expansionary phase is the new energy situation. There is little need to overemphasise the negative effect that rapidly rising energy prices have had on most DCs. Dealing with these effects and finding ways of meeting the associated enormous oil import bills are issues which dominate development thinking at the moment. These concerns are well founded as the amounts involved are substantial. Annual Third World oil imports rose to $30 b in 1975, and to $50 b in 1980 (UNCTAD, 1978; World Bank, 1980). If the cost of oil imports is shown as a percentage of the value of exports, the scale of the problem can be easily seen. One estimate is that for low income countries this figure rose from 9% in 1970 to 19% in 1976, for middle income countries from 10% in 1970 to 22% in 1976.* (Baron, 1980). The 1980 World Bank Development Report presents figures for all developing countries up to 1977 and the ratios are similar to those cited above. According to these figures a number of countries** all had ratios well above 25% (World Bank, 1980). Undoubtedly, the oil price increases in 1979-1980 further exacerbated the situation in individual countries making the current account burden nearly intolerable.***

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* This compares with an average rise from 11% to 24% for the AICs which have a much higher rate of per capita energy consumption. More specifically, Reveille has shown that for 11 Asian countries - Bangladesh, India, Indonesia, Korea, Malaysia, Nepal, Pakistan, Philippines, Sri Lanka, Taiwan and Thailand - the average ratio rose from 6% in 1972-1973 to 16% in 1978 with increases of up to 26%.

** Bangladesh, Ethiopia, Mozambique, Benia, Pakistan, Thailand, Philippines, Paraguay, Syria, Jordan, Jamaica, Turkey, Brazil and Trinidad and Tobago.

*** For instance, even at a constant 1978 volume of oil imports, Thailand's bill for oil in 1980 probably accounted for about 40% of all imports; this cost, combined with its current debt service, would equal about 10% of that country's GNP (Revelle, 1980).

Most developing countries have simply not had the resources to meet the costs implied by the above figures. This can be seen clearly from Table XII which shows that between 1971-73 and 1979-80, deficits incurred by the oil importing developing countries nearly quadrupled in nominal terms.

INSERT TABLE XIV

The size of this debt, and the fact that most observers expect it to grow in the 1980s obviously indicates that the costs of meeting this deficit are bound to severely disrupt the capacity of DCs to continue their present level of development projects. Many other problems stem from the pattern of DC indebtedness that is evolving as a result of the price increases. In order to finance their deficits many DCs were forced increasingly to resort to "non-concessionary" long term loans from the private banking sector. Between 1969-1979, these increased eight times - from $8 billion to $61 billion - a much steeper rate than took place with concessionary loans which only increased by about 100% from $31 billion to $59 billion.* It is perhaps not surprising that this sharp rise in indebtedness is causing considerable dismay within the international economy (OECD, February 1980). See also Griffith Jones, 1980). This concern is heightened by the fact that the five largest borrowers on the private money markets astonishingly account for over 90% of the total. Five of these are NICs - Argentina, Brazil, Meixco, South Korea and Liberia.

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* This new role for the private banking sector is further underlined by the increased share of Eurocurrency loans going to the oil importing developing countries - rising from 22% ($1.5b) of credits to all countries in 1972 ($6.8b) to nearly 44% ($35.4b) of the total in 1979 ($82.8b), Killick (1981).

Three aspects of this situation are important for our concerns. Firstly, the stronger NIC economies clearly have very good access to private sector credit. Lending to creditworthy countries is good banking sense. But the penchant to allow such a high level of concentration to occur clearly makes the banks overly vulnerable to default by one of the big debtor countries - such an event though perhaps unlikely would certainly pose a real threat to the stability of the international banking system.

Secondly, the other side of this concentration is that most of the poorer developing countries have had little recourse to this source of funds in the past. And since most observers estimate that concessionary flows have not adequately filled in the resulting gap, these DCs have probably had little choice but to restrict imports of essential commodities such as spare parts and intermediates, adopted strong deflationary measures and reduce social investments and development projects.
To be sure there is still considerable debate over the nature of the net effects of oil price increases on DC GNP growth in the 1970s. Nevertheless, there is a general consensus that GNP growth rates were reduced somewhat - with the effects on the weaker economies being significantly magnified. (See Baron, 1980). One estimate is that overall growth rates reduced from an average of 6.4% to around 4% over the 1974-1977 period. This is a substantial reduction over such a short period particularly bearing in mind the fact that both figures reflect a tremendous degree of skewness between high NIC growth rates on the one hand and much lower rates for the rest of the DCs on the other. (World Bank, 1980).

The third point relates not to the past but to the future. While DCs did experience oil price related difficulties in the 70s, even these were not on balance as bad as had been expected. Once again the NICs were noteworthy in this case since they were able to maintain high rates of growth in national income and in exports. We believe however, that many more problems lie in store for all DCs in the 1980s as a result of the cumulative effect of both the price rises and the steps taken to adjust to these. A number of factors influence this perception. Most analyses of the impact of oil price rises on DCs, in the 1970s do not take into account the price rises of 1979-1980, their resulting inflationary impact on inputs, and the accompanying sharp downturn in AIC economic growth. As these rises were greater than those in 1973, the retarding effects on DCs are also likely to be much greater - anecdotal evidence of a sharp decline in NIC export performance in 1980 supports this.

Those NICs who were able to maintain their export performance - with it an impressive rate of growth of imports - were able to do this by increasing their external debt and expanding government capital formation (Griffith-Jones, 1980; UNDP/UNCTAD, 1979). In essence these countries postponed any balance of payments adjustments through the use of external finances. A brief look at the experience of South Korea and Brazil is instructive on this issue. In the South Korean case, total net annual foreign capital inflows, consisting mainly of commercial bank lending, grew from $300 million in 1972-1973 to about $2 billion in 1974-1975; this declined somewhat over 1977 and 1978 but shot back up again in the 1979-80 period so that the current account deficit is now about $5.5 billion. (Griffith-Jones, 1980) Brazil's foreign capital supply (which includes net direct investment as well as commercial financing) grew annually from $5.5 billion in 1973 to $8.7 billion in 1974-76. And by 1979 the related current account deficit was in excess of $10.5 billion and will be much higher in 1980. All of this adds up to a total foreign debt of over $60 billion - a considerable drain on any DC even one of Brazil's robustness.

During the period in question these economies stayed buoyant via their export performance and were able to take some of the edge off such a daunting position of indebtedness. It should be noted however that both Brazil and South Korea did not perform at all well in terms of reducing income inequality and redistributing wealth. If anything conditions in these areas suffered a marked deterioration.*

* Other NICs such as Mexico and Argentina have registered equally poor record in the redistribution of income resulting from export led growth. It seems hardly necessary to point out the dismal "adjustment" record of Chile in this regard. The country has successfully promoted exports - between 1973-1978 they grew 150%. But this was done at the expense of a dramatic curb on demand through a sharp drop in government social expenditures (40% in real terms in 1975), a decline in real wages during 1975 of at least 30% below 1969, and an increase in unemployment from 3.8% in 1972 to nearly 17% in 1976. See Griffith-Jones, 1980 for discussion and references on these points.

A number of observers now suggest that many NICs, but South Korea and Brazil particularly, will not be able to "grow their way out" of the crisis created by the second round of price increases. This is a reality they suggest is already manifest in the struggles of the two countries during 1980 when Brazil suffered an 110% rate of inflation and a massive increase in its external debt (yet exports grew at 30%!), while South Korea's GNP dropped by 5% and inflation and external debt increased substantially. Moreover they point to the increasing reticence of the international finance community to make available sufficient funds to allow these countries to continue the balancing act they performed during the 1970s. This reticence to lend extends not only to South Korea and Brazil but equally to the other larger borrowers - and by implication to the smaller, weaker economies as well. The banks are simply not prepared to act as financial back stop to DCs without having a much more significant say in the domestic fiscal affairs of the country in order to ensure the security of their investment. (Griffith-Jones, 1980; UNDP/UNCTAD, 1979; Killick, 1981). If this is true the NICs could then be caught in a double bind. They already face, as we have argued much more difficult international trading conditions which they can only overcome by keeping their intermediate imports high, maintaining investment in new capital stock and in expensive training schemes, providing extensive government support for exports, etc. If the resources to do this are not forthcoming or else are available only on deflationary terms, then export growth must decline and , with it, at least in the short run, national income levels (leading to even greater distributional problems).

The point about external interference in domestic fiscal policy is an important one not only for the NICs but for all oil importing DCs. If DCs are forced to finance their oil related current account deficit by recourse to concessionary loans, as many already have, it is quite likely that they will have no choice but to accept the imposition of very deflationary policies as a precondition for being granted the loan. This has always been the case but given present conditions there is reason to believe that the restrictions will be even more severe and further will be accompanied by a higher degree of inflexibility on the part of the lenders. The recent example of Jamaica's failed negotiation with the IMF are a case in point. Former Prime Minister Manley refused to give in to the Fund's deflationary requirements. The fund refused to give in to Manley. For this and other reasons an election was called and the Manley government was replaced with one more amenable to follow the deflationary policies advocated by the Fund.* NICs were able to resist this sort of pressure and interference in the past, and probably will be able to counter some of it in the future even if they do accept concessionary funds. Other countries however may not fare so well. We believe their capacity for independent adjustment was substantially exhausted during the 1970s. The pressure imposed by the 1973-74 oil price increases lead many DCs to attempt to make cuts in imports, reduce energy consumption, cut back on non-essential projects to the extent that they were capable. Even if these moves were not successful or were inadequate and contradictory in an objective sense, they were probably the best that could be done under the highly unusual conditions in which policy makers suddenly found themselves.

We would argue that the margin for these countries to achieve further savings in the 1980s without receiving outside financial or technical assistance from the multilateral agencies probably is fairly slim.** recent era of restricted access to essential inputs, spare parts, etc. has probably left the industrial and the agricultural infrastructure in a pretty precarious position. Replacement investment and maintenance activities may well have been slowed down considerably due to the resulting lack of resources. Hence as the DCs move into the 80s trying to adjust once again to the unavoidable shocks of the second oil price rise, the external imposition of further restrictions on demand and development projects can only exacerbate what is already a difficult situation. We fear that among many other impacts that may occur, this combination of factors related to the oil price rises will probably further limit the capacity of non-NICs to shift resources into the development of manufactured exports. In the short run the resources almost certainly will not be there -

* Tanzania, too, has more recently rejected a similar offer from the Fund - however, the nature of the resolution of Tanzania's crisis cannot yet be predicted.

** Some authors such as Seers (1981) argue that the extension of aid to the poorer DCs to assist them in their present crisis may be to their advantage by making them more independent of the world economy.

in the longer run it is as yet impossible to judge what the cumulative effect of the 1970s has been on industrial capital stock (in both physical and human terms).

Much of the literature concerned with the balance of payments adjustment process strongly emphasises the need for DCs to switch resources into the export sector as one way of reducing the pressure of oil deficits. (See Griffith Jones, 1980). Some of this discussion does recognise that the poorer, less industrially robust DCs will have more difficulty than the NICs in making this switch. We expect however, that it is easy to underestimate the difficulties that could be encountered by many countries in making this switch efficiently and within a period of time where it will be effective. This is because firstly the poorer countries are starting from a very low base - in the sense that achieving production that is competitive internationally does take time, often require new techniques, higher skill levels, etc., particularly if the country has never exported in that area. Secondly the industrial capital stock on which such a strategy will build may, as we have suggested, been neglected in recent years in some of the poorer NICs and hence will take some time to rebuild. Thirdly, difficulties will also be encountered because of our earlier arguments that producers of even relatively standard products may now require a greater degreee of product or process know how to be able to compete internationally. Hence it seems that calls for non-NICs to willy nilly increase their exports in response to short term energy problems need to be examined very carefully from a policy point of view. It is by no means clear what these calls mean in policy terms as to the sectors to be selected for export promotion, the opportunity costs involved in devoting resources to the task, and the time it will take to achieve any measurable result.

SECTION V PRIORITIES AND POLICY OPTIONS FOR DEVELOPING COUNTRIES

The Need for a Response

We have reviewed some aspects of the restructuring process currently taking place in the international economy. Our discussion centering on technical change and innovation policies in the AICs, has suggested that some trends are evolving which, contrary to the predominant restructuring wisdom, pose serious adjustment problems for DC policy makers. For the Third World the most immediately obvious impact of these trends has been to worsen the international trading environment for manufactures. Rather than being an area where DCs can continue to enjoy a steady improvement in their performance, we believe that, except for a few NICs, prospects for the resumption of rapid growth in exports in the near future are very bleak. This analysis is based on three elements - the retarding effect on DC exports of reduced growth and slack demand in the AICs which shows little prospect of early change; the resultant increased wave of protectionist sentiment which is concentrated on those sectors where DC's hope to make substantial inroads; and finally the increased importance of technical change as a determinant of international competitiveness.

Our consideration of the latter element has emphasised two related aspects. Firstly, the general increase in the importance of technical change in international trade has been given considerable impetus by the advent of microelectronics. The competitive advantage likely to be conferred upon firms and countries able to develop and incorporate MRIs in the product and process technologies will be considerable. Moreover, there is every reason to expect that these changes will take place in sectors where DCs are hoping to build on their established comparative advantage to expand exports to AICs. Secondly, despite their ruinous fascination with deflationary policies in the midst of rising unemployment, AIC policy makers have begun to shift resources and effort towards intervention in innovation. The explicit intention is the maintenance and improvement of their international comparative advantage which they see as resting firmly on the successful diffusion of new technology. Hence the overall emphasis of AIC innovation policy on encouraging the development of national capability in the production and use of microelectronics.is aimed to reverse declines in comparative advantage and seize a greater share of international trade against all competitors

We have suggested that the cumulative effect of these trends could seriously disadvantage Third World countries trying to build up their exports of manufactures. Technical changes introduced by innovating firms in the AICs may significantly improve total factor productivity and hence erode DC comparative advantage in sectors crucial to the economy in terms of foreign exchange earnings, employment, and backward linkages central to their export led industrialisation strategies. The use by AICs of tariff and non-tariff barriers to limit DC access* to domestic markets contributes to the curtailment of the sort of export opportunities that were so crucial to the NICs in the 1960s.

Failure on the part of DCs to respond and adjust to these changes will inevitably extract a high social and economic cost - as the experience of some countries has already shown. Yet nearly a decade of rising energy costs has stretched the capacity of all DCs to continue to generate the resources needed for investment in development projects. For many the main economic priority is to stave off near continual balance of payments crises by cutting back government expenditure and increasing short-term borrowing. The social and economic costs of these policies means that many of the poorer countries will simply have to forego hopes for significant industrial development and income growth in the short to medium term. To a very real extent the low-level trap faced by these countries effectively eliminates them from considering many of the policy initiatives discussed in this paper. (See UNCTAD, 1981; UNIDO, 1981; for a discussion of the particular problems of the least developed countries).

For DCs whose industrial base affords the opportunity to develop an export capacity, the questions we have raised in terms of a changing international trading environment make it hard to avoid querying the continued viability of export-led industrialisation strategies which are presently advocated by many observers. In raising such a question an important, multi-faceted distinction needs to be made between the NICs and other countries.

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* While at the same time using offshore assembly provisions in those same laws to increase the amount of trade managed by AIC firms.

In the case of the NICs, underlying their notable export performance in the 1960s is a highly diversified and integrated industrial structure based on a significant degree of indigenous technological capabilities and sophisticated planning and management cadres. The accompanying expansion of domestic demand in line with export growth has been an equally important determinant of success - and my yet prove to be the most significant factor in maintaing their performance in face of declining export opportunities in the future. All of these aspects contributed to the resilience of their economic and enhanced their capacity for rapid adjustment which allowed them to grow their way out of the oil price-induced recession of 1974-75. As we suggested earlier the external conditions which facilitated NIC economic growth in the 1960s have changed and the convenient coincidence of cheap external financing, accessible markets, growing AIC demand for import and large unit cost differentials have probably disappeared for ever. It would obviously be foolish to suggest that as a result these countries should abandon their export oriented policies for some less certain alternative economic strategy. However, we believe it is clear that even the NICs must respond in quite fundamental ways to current changes or else risk a drastic reduction in the curretn level of economic well being.

For non-NICs, the pressure to move away from a commitment to export led growth seems more compelling. But the liklihood of easy success seems equally problematic if only because they will still have to deal with the weaknesses that makes their capacity to greatly expand manufactured exports under current conditions suspect. Relative to the NICs, these countries are obviously less well off in many of the areas which determine their capacity to respond in the face of external shocks. Many of these involve dependent linkages with the AICs of one sort or another which can inhibit their attainment of industrial independence and limit the economies "capacity to transform" itself (Kindleberger, 1962; cited in Roemer, 1981).

Poorer DCs are frequently characterised by an excessive degree of dependence in four areas: (1) final product market dependence on one or a few (export) products or markets; (2) technological dependence, particularly in the area of capital goods which are seen as important sources of indigenous innovation; (3) managerial and entrepreneurial dependence and (4) foreign capital dependence due to existing patterns of input requirements and more recently energy use.

The combined effect of these dependent linkages reduces the inherent strengths of these economies and inhibits the speed and efficiency with which resources can be shifted to export sectors to earn foreign exchange. From this perspective clearly a major obstacle to future development is the economy's degree of dependence on its external environment. Given this, it is, of course, tempting to respond by calling for thses countries to abandon any pretension at achieing growth through the expansion of manufactured exports and urge them instead to explore the possibilities of more inward-looking forms of development. A number of authors have begun to advance arguments which make the case for development strategies that involve a certain degree of "delinking" from the North (Seers, 1981; Kaplinsky, 1981; CEPAL Review, 1980) - and which under certain rigorous assumptions could lead to a signficiant degree of industrialisation.**

This is not the appropriate context to elaborate on the details of an inward looking development strategy except to emphasise that it need not imply the sort of autarchic isolation that seemed the logical outcome of the prescriptive analytics of the dependency and self reliance schools (Hoffman and Unger, 1978; Roemer, 1981). Nor to equate the notion with the equally beleagued era of import-substitution policies. However, policy efforts to limit or reduce those external linkages which are most damaging seem entirely in line with the current realities of the non-NICs.

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* However almost paradoxically large NICs such as Brazil and India with their huge domestic markets arguably stand a better chance of succeeding until an inward looking strategy than either smaller NICs or the poorer inherently more dependent non-NICs.

** See Cooper, 1981 for a thought provoking discussion of the possibilities of the Raj-Sen closed economy model being applied in response to present conditions.

A good deal of delinking has undoubtedly already happened (Seers, 1981). In the urban sector high energy prices have worked against the continued importation and perhaps operation of energy intensive techniques. (Baron, 1980). Public transport, bicycles and rail and maritime freight become more attractive than the use of the automobile and trucks. Even the enforced isolation of rural areas may have its benefits by increasing the attractiveness of low energy using agricultural production and reviving craft techniques.*

Moreover, future investment decisions are already being evaluated not only in terms of their energy intensiveness but also on their requirements for expensive (foreign exchange) inputs and services for operation and maintenance. This sort of de-facto shift in strategy will lead to significant changes in the evolving industrial structure in the non-NICs even without formal decisions to pursue inward looking growth strategies.

These developments may lead to decisions to develop a labour intensive capital goods sector capable of meeting the more modest needs of domestic oriented industrial activities. If so the costs will certainly be high during the learning period - but even in DCs with small domestic markets the possession of a mchine building capacity must still be considered essential to independent industrial development (Pack, 1981; Cooper, 1981). THis "conventional" wisdom has received massive empirical support in recent years - to our minds the inescapable logic of the arguments is only increased by a consideration of the effects of higher energy prices.

If such strategies make sense for individual countries, it also seems essential that interregional co-operation and collaboration arrangements, whose "integrity" suffered severely in the 1960s and 1970s will also need to make a comeback; albeit in a revamped form. The long term viability of the early groups was always suspect when they were based on admirable but fragile intellectual arguments for Third World solidarity

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* While we share Seers (1981) optimism about the unrealised resilience of rural economies, the experience of Brazil which chose to secure petrol supplies to the urban elite by means of exploiting the rural agricultural sector suggests that the improvement of equity has not uniformly occurred throughout the Third World as a result of oil prices.

and collective self-reliance - many of them emanating from liberal minded but North based thinkers. The favourable prospects for development based on international rather than regional linkages allowed nationalistic self-interest to intervene (effectively exploited by Northern actors) when the issue of collective costs and collective sharing arose in regional forums. These lead for instance to the disintegration of the East African Community and the disembowment of the Andean Pact. However, one suspects that with the changed climate national self-interest particularly among the poorer countries, will now dictate new attempts at regional collaboration - even if these are only perceived as the best means of saving their own country from economic ruin. The truly dynamic potential of regional groupings (as was demonstrated in the early days of the Andean Pact; see JUNAC 1976) was never really given chance in earlier periods - hopefully present circumstances may provide another opportunity (See O'Brien, 1981).

We do not wish to pursue the specific nature of inward-looking policies any further and would advise the exercise of restraint, however, in going too far towards advocating non-NICs to abandon export led strategies in favour of such policies. The internal and external circumstances of countries differ far too much to allow a "formalised" inward-looking development strategy to be a priori any more suitable to the mass of DCs than their export led counterparts. Indeed, it is almost certainly a mistake to see the two sorts of approaches as being mutually exclusive either in conceptual or in practical terms - particularly since the reality is that both sorts of policy have been simultaneously pursued by many countries.

Rather than opting for one model or the other as the <u>principle</u> strategy, it seems more sensible for DC policy makers to evolve and implement the mix of policies necessary to ensure that damaging external linkages are minimised and the economy is able to respond quickly and efficiently to future externally imposed changes in its environment. The development of sectoral strategies could therefore aim to build on the strengths and eliminate the weaknesses of each sector in terms of the <u>nature</u> of its external linkages. Some branches might best develop managerial talent and technological capacity and reduce foreign exchange requirements by concentrating on building up its domestically oriented activities while others would necessarily be best suited to export promotion.

While this undoubtedly already happens in many countries it does so in an ad hoc fashion which can often have high opportunity costs. Moves to develop an export base by relying on foreign participation in assembly operation in export processing zones are a case in point - the resulting short run foreign exchange benefits are often simply not great enough to forego the costs of missed opportunities to develop local capabilities which such zones eliminate almost by definition.

What is required is for DC policy makers to undertake a much more complex and long term evaluation of the relative contribution that each sector can make to national objectives along the lines suggested above. This is no more than good planning practice and similar recommendations have been made in other contexts. However, our earlier emphasis on the potential changes in international trading environment due to AIC controlled/dominated patterns of innovation and technical change suggest that decision to pursue an export or domestic oriented strategy in particular sectors must necessarily be reflected in the sector/firm strategy vis a vis the acquisition of technology. This seems particularly true in relation to the further development of export oriented sectors. Pressure to compete internationally have always required AIC firms to adopt best-practice techniques. This has been less the case for DC firms because of the unit labour cost differential they enjoyed. We believe that it will become much more difficult for DCs to continue to rely on this element alone to allow them to use techniques which are too far from the best practice frontier. Maintaining their existing position and breaking into new sectors will involve the mastery of inherently more complex product and process technologies which may be more costly to acquire and which will certainly require a more intensive application of entrepreneurial, managerial and technical skills.

In the new era of protectionism, gaining market access will alos necessitate closer links with foreign intermediaries - the identification and penetration of market niches by independent DC firms will require much more aggressive and sophisticated marketing techniques.

Some Final Thoughts on the Implications of New Technologies

Where the application of new technologies are involved, the process of developing the required levels of indigenous expertise will be a long term one requiring hurge investments in skill formation and necessitating close and costly collaboration between public and private sectors and between recipient and technology supplier.

Given the heterogenous nature of the DCs, the effects of the use of the new technologies will differ significantly across Third World countries. The NICs arguably have the economic strength and technological capacity to adapt to a rapidly changing competitive situation in the world economy that may result from the use of MRIs by AIC.firms. It is equally plausible, however, that for some of these countries, the nature of their integration into the world economy will prove problematic. Those NICs which are subject to a high degree of outside control in particular sectors likely to be affected by MRIs, may be largely unable and unwilling to influence decisions by foreign firms on location of production /or on their local competitive strategies which could be destabilising within the local economy.

DCs which are only beginning to diversify their industrial activities and look towards exports to AIC markets as a major engine of growth, face an additional set of obstacles. Unlike the NICs, these countries probably do not have the technical capacity to respond to changes in competitive conditions. The technological requirements for competing in high income markets will be beyond the capabilities of many countries. Due to their weak bargaining position they will not be able to rely on the free operation of the market to acquire access to the technical knowledge needed to exploit the new technology - imperfections which are likely to exist in particular sectors for the NICs as well.

Changes in comparative advantage might necessitate a fundamental reorientation of industrialisation strategies. New strategies could include either pulling out of producing exports for AIC markets altogether or shifting the focus of their export efforts to other DCs - a shift which might not necessitate changes in methods of production if AIC competition can be kept at bay through tariffs and quotas. Alternatively, the decision might be taken to continue to export to AICs by becoming technologically competitive in traditional sectors or in entirely new areas such as in the export of software packages to other DCs. Obviously between these options there will be any number of intermediate positions that might be the optimal response to the particular conditions faced by the country. This decision, inter alia, implies a decision to exploit the potential benefits afforded by the use of microelectronics. In this case different types of technological capability (related to the exploitation of the technologies) will also have to be created or acquired in order to meet the objectives.

However, because of the complex issues raised by the use of microelectronics within DCs, the generalised arguments about the trade offs involved in investing in the creation of technological capabilities need to be closely examined (Cooper and Hoffman, 1978). The debate has previously centred around the relative cost and benefits of importing foreign technology as opposed to developing it locally. In its purest form, the comparative cost argument inevitably dictates that greater use of local skills and resources can only result in a high degree of social cost and loss of welfare in the short term. However, the argument (and the evidence) that the generation of technological skills can create significant economic gains in the form of externalities has gained a good deal of credence. Nevertheless, major difficulties have been encountered in ensuring that such arguments are translated into effective policies. For instance, problems exists in measuring the resultant benefits which are not valued by the market. This in turn makes it nearly impossible (at least on the basis of existing evidence) to establish clear guidelines on the optimum level of investment in local capabilities (an easy task theoretically, but not practically). These problems are seriously compounded by our current inability to specify precisely which skills should be developed and in what quantities. (Cooper, 1981)

Despite these problems, the arguments in favour of developing local technological capabilities are, in fact, greatly reinforced by the nature of microelectronics technology. It can be utilised in all productive activities with significant gains in both capital and labour productivity. This could mean that the externalities associated with creating the ability to use and innovate with microelectronics could be even larger than those normally associated with capability accumulation in more narrowly defined areas of technical activity.

Crucial to capturing the potential gains in this situation would be the creation of an indigenous software capability in the development of industrial appliations of microelectronics. The ever increasing importance of software could be a development which is particularly favourable to DCs. Although there will inevitably be strong pressures by AIC suppliers to fully appropriate software, the very nature of the competitive process must lead to considerable "leakages" in the market. These could be exploited by DCs to gain initial access to the technical knowledge needed to create a small but viable software capability which could be of general use or be more specifically oriented to the needs of particular sectors. Specialisation in the development of software packages particularly suited to DC conditions would appear to be a very real possibility somewhat along the lines of Third World exports of other types of disembodied technology (such as providing the civil engineering for roads and dams in other DCs). At the moment we know very little of what the costs are likely to be in developing a software capability or the best means to do it under DC conditions. However, if the existence of an indigenous software capability, well integrated into production activities proves to be the key factor that AIC commentators believe it will be, then DC policy-makers are well advised to examine this as a serious policy option.

The constraints on many DCs being able to develop microelectronics using an innovative capability are, of course, likely to be severe - even though as we have mentioned some NICs are already beginning to develop just such a capability. There are certain factors, however, which would at least allow us to speculate that the opportunities for Third World countries to develop technically and economically viable innovations incorporating microprocessors may be much better than would appear at first.

If the overwhelming bulk of innovative activities are taking place within AIC firms, this means that the applications that are developed will reflect AIC conditions, particularly as regards the perceived economies of scale required to make automation viable. However, the inherent flexibility of the technology would indicate, a priori at least, that applications involving small scale batch methods of production might be equally possible, particularly if the same amount of emphasis, time and cost were put into this type of application as opposed to those at the other end of the scale.

If such an alternative direction of technical change is now much more feasible because of the advent of microelectronics, then it might conceivably be sensible for some DCs to concentrate some of their efforts on developing this type of innovative capability in specific sectors. If such a strategy were considered feasible by DCs it would of course need to be formulated and implemented within a comprehensive framework that took account of the fact that the large bulk of productive activities need not necessarily depend on the use of microelectronics but nevertheless need considerable attention as well. To discuss the implications of such a strategy would take us further into the realms of speculation than we would like to go at this point so we shall leave it to be debated in another context. However the point about long term planning within a comprehensive framework is an important one to close on - ad hoc responses to the changing nature of the international economy which confronts the Third World can, no matter how justified individually lead to very significant long term costs if they are not co-ordinated and oriented to achieve a clearly specified set of national objectives. The severity of the current crisis necessitates that DC policy makers must respond, possibly in a fundamental way, by changing their strategies to adapt to new conditions.

Certainly, either directly or indirectly, the Third World will be affected by the coming changes, whatever their rate and magnitude. The developing countries do have the opportunity to influence the impact of these changes in their own societies. However, they must act soon and they must act informatively on a broad range of fronts in order to ensure that the net effects are positive rather than negative. This discussion has been a very limited attempt to contribute to this process.

TABLES VII AND XI INCLUDED IN TEXT

Table I : Levels of Unemployment 1929-35 and 1976-81[a,b]

Countries	1929	1930	1931	1932	1933	1934	1935	1976	1977	1978	1979	1980	1981
Belgium	0.8	2.2	6.8	11.9	10.6	11.8	11.1	6.8	7.8	8.4	8.7	9.4	10.6
Denmark	8.0	7.0	9.0	16.0	14,5	11.0	10.0	4.7	5.8	6.5	5.3	6.2	8.0
Germany[c]	5.9	9.5	13.9	17.2	14.8	8.3	6.5	4.1	4.0	3.9	3.4	3.4	4.1
France	1.2	na	2.2	na	na	na	na	4.3	4.8	5.2	6.0	6.4	7.1
Ireland	na	na	na	na	na	na	na	9.4	9.2	8.4	7.5	8.3	10.0
Italy	1.7	2.5	4.3	5.8	5.9	5.6	na	5.6	6.4	7.1	7.5	8.0	3.3
Netherlands	1.7	2.3	4.3	8.3	9.7	9.8	11.2	4.3	4.1	4.1	4.1	4.8	6.3
United Kingdom	7.2	11.1	14.8	15.3	13.9	11.7	10.8	5.3	5.7	5.7	5.3	6.9	9.4
U.S.A.	3.1	8.7	15.2	22.3	20.5	15.9	14.2	7.7	7.0	6.0	5.8	7.1	7.2

Source: 1929-1935 Maddison, A. (1980), "Western Economic Performance in the 1970s: A Perspective and Assessment", Banco Nazionale del Lavoro Quarterly Review, no.134 September, pp.247-290.

1976-1981 EEC-European Economy, March 1981; and EEC-Short term indicators April 1981.

a : 1929-1935 as a % of total labour force ; 1976-1981 as a % of civilian labour force.

b : 1981 first three months only.

c : the Federal Republic for the period 1976-1981.

Soete (1981)

Table II : Productivity Growth in Industry in the 70's (EEC-9)

Year	Belgium	Denmark	Germany(FR)	France	Ireland	Italy	Luxemburg	Netherlands	UK
1971	4.2	6.2	2.1	4.7	3.8	-1.0	-3.6	3.9	3.3
1972	9.2	5.0	4.7	5.0	5.8	4.9	3.4	6.0	6.0
1973	9.4	2.7	5.7	4.4	5.9	8.5	7.3	9.2	7.0
1974	2.4	5.5	4.1	2.3	-0.4	3.7	2.0	4.3	0.0
1975	-1.4	7.1	0.7	1.7	-7.0	-9.4	-18.0	-2.4	-0.6
1976	13.0	7.5	9.2	8.6	10.6	12.4	7.6	12.0	6.8
1977	4.0	3.3	3.8	4.0	3.1	2.0	3.3	3.4	0.2
1978	5.8	3.1	1.8	4.0	4.5	2.8	10.8	3.6	1.7
1979	7.1	3.7	4.3	5.1	5.0	6.9	5.8	4.0	1.2
1980	3.3	1.9	1.2	2.7	-1.8	5.0	0.1	2.9	-4.2
1981*	3.0	1.5	2.4	1.8	6.9	-2.9	-4.4	4.1	2.6

Source: EEC-European Economy, March 1981.

* estimated.

Soete (1981b)

Table III

Trends in expenditure on R & D as a percentage of GDP in selected countries, total, defence and other

	*1963**	*1967*	*1971*	*1975*
France				
total	1.60	2.20	1.90	1.80
defence	0.43	0.55	0.33	0.35
other	1.17	1.65	1.57	1.45
Germany				
total	1.40	1.70	2.10	2.10
defence	0.14	0.21	0.16	0.14
other	1.26	1.49	1.94	1.96
Japan				
total	1.30	1.30	1.60	1.70
defence	0.01	0.02	–	0.01
other	1.29	1.28	–	1.69
United Kingdom				
total	2.30	2.30	2.10[a]	2.10
defence	0.79	0.61	0.53	0.62
other	1.51	1.69	(1.57)	1.48
United States				
total	2.90	2.90	2.60	2.30
defence	1.37	1.10	0.80	0.64
other	1.53	1.80	1.80	1.66
Netherlands				
total	1.90	2.20	2.00	1.90
defence	–	–	0.04[a]	0.03
other	–	–	(1.96)	1.87
Sweden				
total	1.30	1.30	1.50	1.80
defence	0.40	0.43	0.23[b]	–
other	0.90	0.87	(1.27)	–
Canada				
total	1.00	1.20	1.20	1.00
defence	0.09	0.09	0.06	0.04
other	0.91	1.11	1.14	0.96
Italy				
total	0.60	0.70	0.90	0.90
defence	0.01	0.02	0.02	0.02
other	0.59	0.68	0.88	0.88

*Germany, Netherlands, Sweden, United Kingdom: 1964.
[a]1972.
[b]1970.
Source: OECD (1979), *Science and Technology in the New Socio-Economic Context.*

FIG.1 : Industrial Output and Employment in the EEC-9, 1950 to 1980 (1962=100).

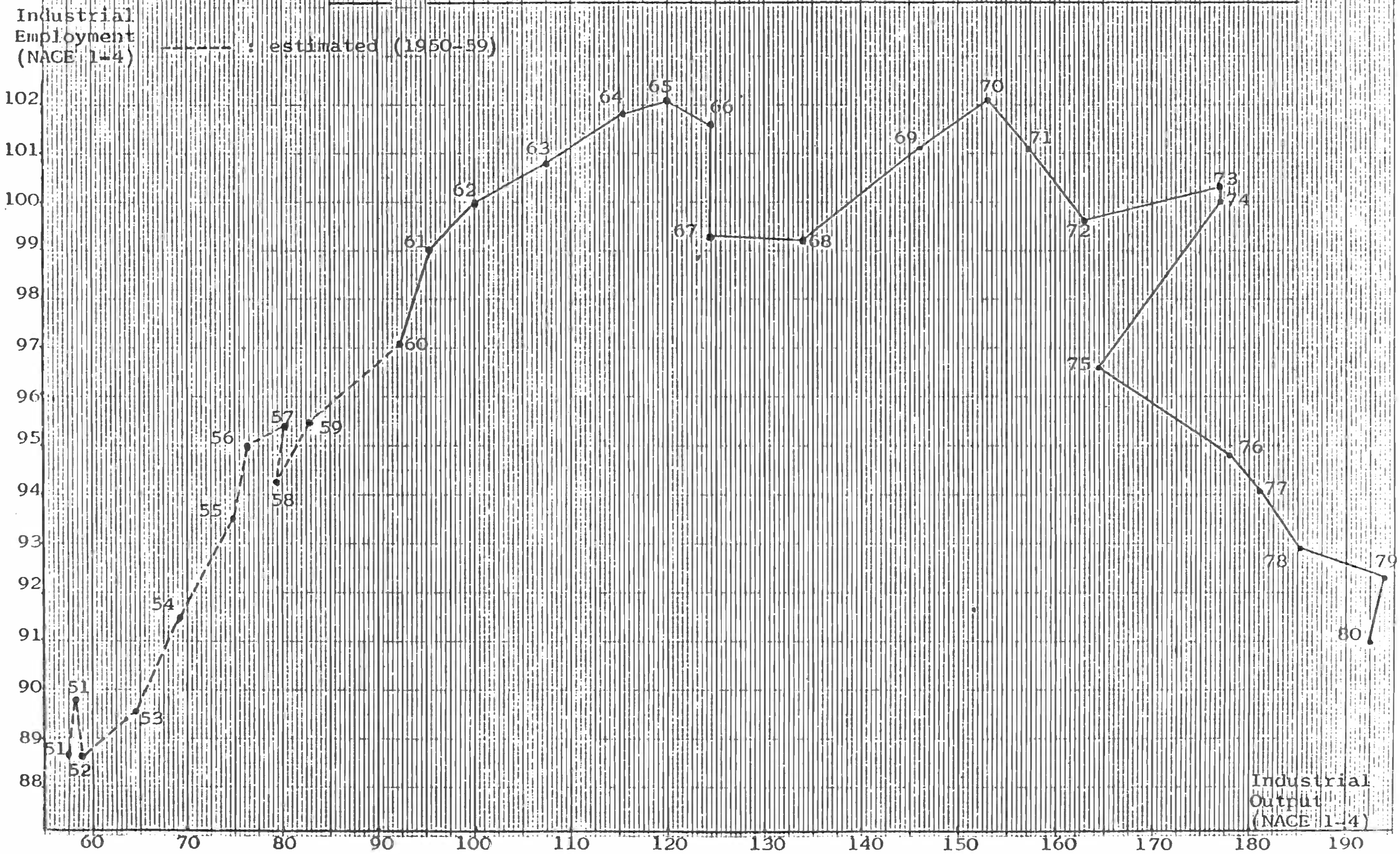

Figure II

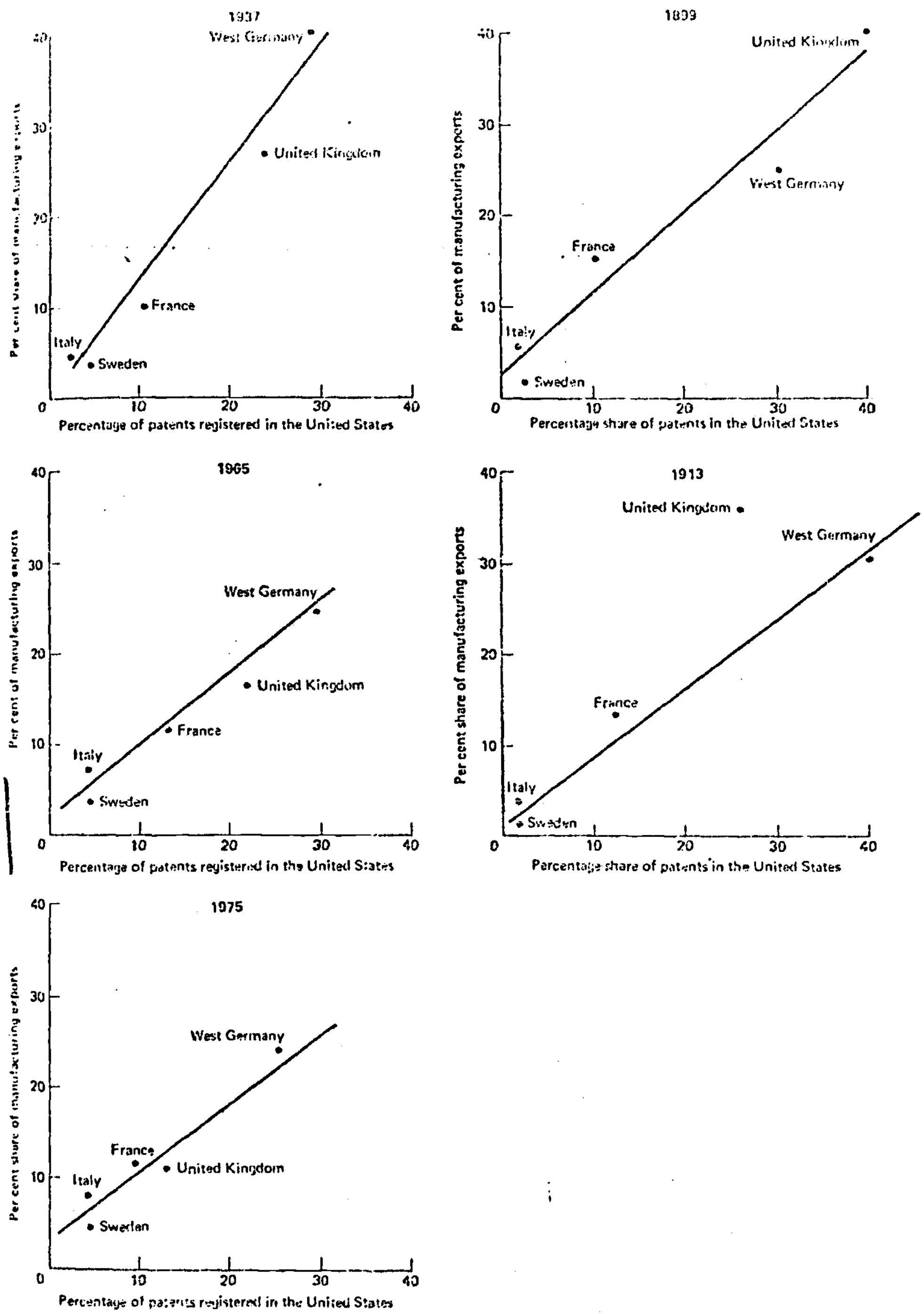

Fig. 3.1 Percentage share of manufacturing exports versus share of patents registered in the United States in 1899, 1913, 1937, 1965 and 1975

Source: Pavitt and Soete (1980)

Table IV

Inter-country regression results for 40 SIC industries (1974)

Industry	*United States SIC*	*t-value b coefficient*	R^2	*(United States) Applied R & D/value added*
*(1) Significant results**				
Drugs	283	12.12	0.89	9.05
Special industrial machinery	355	12.13	0.89	1.33[a]
Metalworking machinery	354	11.99	0.88	1.00
Engines and turbines	351	8.40	0.79	11.07
Instruments	88	8.24	0.78	7.65
Electrical transmission and distribution equipment	361, 3825	7.88	0.77	8.23
Ordnance, guided missiles	348, 376, 3745	7.50	0.76	43.48
Electrical industrial apparatus	362	7.30	0.74	6.18
Industrial inorganic chemicals	286	5.86	0.65	3.08[b]
Office and computing machinery	357	5.42	0.61	18.79
Communications and electronics equipment	366, 367	4.49	0.52	22.45
Aircraft	372	4.34	0.51	19.13
Electrical lighting, electrical equipment	364	4.17	0.48	3.70[c]
Soaps, cleaning products, etc.	284	4.07	0.48	3.12[d]
Construction machinery	353	4.13	0.47	3.12
Miscellaneous chemical products	289	3.68	0.42	3.12[d]
Fabricated metal products	34	3.48	0.41	2.73
General industrial machinery	356	3.52	0.40	1.33[a]
Industrial organic chemicals	281	2.92	0.31	3.08[b]
Petroleum products	13, 29	2.79	0.30	2.53[e]
Miscellaneous machinery	359	2.67	0.30	1.33[a]
Motor vehicles	371	2.81	0.30	8.43
Railroad equipment	374	2.71	0.28	3.83[e]
Refrigeration and service machinery	358	2.51	0.25	1.33
(2) Non-significant results				
Radio and TV receiving equipment	365	2.20	0.23	2.44
Plastic materials	282	2.21	0.22	7.92
Miscellaneous electrical equipment	369	2.24	0.22	3.70[c]
Electrical household appliances	363	2.16	0.21	3.70[c]
Rubber products	30	1.82	0.18	2.09
Textiles	22	1.59	0.15	0.7
Farm machinery	352	1.62	0.12	3.08
Miscellaneous transportation equipment	379	1.53	0.12	3.83[e]
Stone, clay, glass products	32	1.32	0.11	1.13
Non-ferrous metal products	3336, 3398, 3463	1.33	0.11	0.87
Ferrous metal products	331, 332, 3399, 3462	1.30	0.10	0.61
Food	20	0.99	0.08	0.58
Agricultural chemicals	287	1.08	0.07	3.51
Motor and bicycles	375	0.61	0.06	3.83[e]
Paints and allied products	285	0.52	0.03	3.12[d]
Ship and boat building	373	0.47	0.03	3.83[e]

*Significant at the 1 per cent level.
[a] R & D/value added figures were only available for the group of SIC 355, 356, 358, and 359.
[b] R & D/value added figures were only available for the group of SIC 281 and 286.
[c] R & D/value added figures were only available for the group of SIC 363, 364, and 369.
[d] R & D/value added figures were only available for the group of SIC 284, 285, and 289.
[e] Estimated.
[f] R & D/value added figures were only available for the group of Standard Industrial Classifications.

Soete (1978)

Table V

Industrial innovation policies — overall strategic goals

Canada	*Japan*	*The Netherlands*	*Sweden*	*United Kingdom*	*United States*
(a) More industrial innovation (I),* to achieve	(a) More industrial innovation (I), to achieve	(a) More industrial innovation (I), to achieve	(a) More industrial innovation (I), to achieve	(a) More industrial innovation (I), to achieve	(a) More industrial innovation (I), to achieve
(b) technological sovereignty (XIX)	(b) security (XVII) in	(b) improved international competitiveness in Dutch industry (II),	(b) improved international competitiveness in Swedish industry (II)	(b) improved international competitiveness in UK industry (II),	(b) improved international competitiveness in US industry (II)
	(c) defence (XX),	(c) more jobs (V),		(c) improved economic performance (VI),	
	(d) energy (XI), and	(d) better quality jobs (XVIII),		(d) more jobs (V), and	
	(e) employment (V)	(e) selective economic growth (VI), and		(e) better jobs (XIII)	
		(f) better public services (XIV)			

*The bracketed Roman numeral identifies one of the benefits of innovation listed in Figure 5.1.

Source: Rothwell and Zegveld, 1981

Table Va

Industrial innovation policies – main policy measures

Canada	*Japan*	*The Netherlands*	*Sweden*	*United Kingdom*	*United States*
**					
a.1 Innovative-conscious procurement (9)* a.2 Major government programmes (1) b.1 Sponsor companies (5) b.2 Encourage consortia and joint ventures (8) b.3 Aid to small firms (5) c.1 Sectorally orientated technical centres (2) d.1 Secure maximum advantage for Canada from imported technology (2) d.2 Coordination of importing of technology so as to foster selective development of Canadian technological capability (2)	(Not specified in English abstract version)	a.1 Help large firms meet costs and risks of R & D (5) a.2 Ensure small firms use advantages (for example, flexibility) (8) b.1 Reorientate Dutch R & D to social and industrial problems (2) b.2 Research in new areas of technology (2) b.3 Better use of existing expertise (2) c.1 Coordination of consultation and information services (4) d.1 Innovation-conscious procurement (9) d.2 Innovation-conscious regulation (8)	a.1 Broaden markets+ a.2 Standardization+ a.3 'Niche' strategies+ a.4 Search for new markets (for example, in developing countries)+ a.5 Exploit national advantages (for example, resources, technical competence)+ b.1 Improve school curricula (3) b.2 Improve university courses (3) b.3 More technical and scientific research (2) c.1 Funds for research in new technologies (5)	a.1 Mature industries (a) import technology (4) (b) coordinate public and private sectors (8) a.2 'Laggard' industries (a) R & D batch production+ (b) monitor technological changes abroad and import (4) a.3 Service industries (a) more R & D (1) a.4 New industries (a) coordinated national strategy (8) d.5 Small firms (a) better consulting services (4) (b) better technology transfer (for example, from large firms) (4) (c) aid for R & D (5) d.1 Better university–industry liaison (3)	a.1 Information centre on federally supported R & D/technology (4) a.2 Foreign technology information (4) b.1 Generic technology centres (2) b.2 Regulatory technology research (2) b.3 Improved university–industry cooperation (3) c.1 Uniform government patent policy (7) c.2 Improved patent service (7) e.1 Funds for small firms (5) e.2 Corporations to sponsor innovation (like NRDC) (5) e.3 Increased venture capital (5) f.1 Uniform procurement policies (9) h.1 Develop a technology forecasting system (8) i.1 Award for innovation (8)

*The bracketed number refers to the type of policy tool involved (see Figure 5.2 for list of policy tools).
†No policy tool (apart from government exhortation) specified for these policy measures.
**The figures a, b, c, etc., relate to the tactical objectives listed in Table 5.8

Source: Rothwell and Zegveld, 1981

Table VI

Industrial innovation policies — tactical objectives

Canada	*Japan*	*The Netherlands*	*Sweden*	*United Kingdom*	*United States*
(a) Increased demand for Canadian technology (i, vii and viii)*	(a) Gradual change in industrial structure (vi)	(a) Increased capacity for innovation in industry (iv and v)	(a) Improved performance in traditional sectors (iii)	(a) Strategies for industrial sectors (i, ii, iii, iv and v)	(a) Improved technology transfer (ii)
(b) Expand Canadian industry's potential to develop technology (ii)	(b) Identification of future areas of growth in industry (iii)	(b) More government R & D (ii)	(b) Strengthen the knowledge base (ii)	(b) National policy to coordinate for example employment (v)	(b) Increased technological knowledge (ii)
(c) Strengthen capacity of firms to absorb technology (ii)	(c) Construction of innovation policies after public consultation	(c) Better consultation and information services (ii and iii)	(c) Identify and exploit new technological prospects (ii)	(c) Increased technological research (ii)	(c) Improved paten[illegible] system (v)
(d) Import technology under favourable terms (ii)		(d) Increased demand for innovation to satisfy public needs (vi and vii)		(d) Better consultation and information services (ii and iii)	(d) Improve antitrust policy (v)
				(e) More/better trained manpower (especially engineers) (ii)	(e) Foster development of small innovative firms (iv and v)
					(f) Improved feder[illegible] procurement (vii)
					(g) Improved regul[illegible]tory system (vi)
					(h) Facilitate labour/management adjustmen[illegible] to innovation ([illegible]
					(i) Supportive attitude to innovation (v)

*The bracketed Roman numerals refer to the intended target (listed in Figure 5.2) of the various policy measures (see Table 5.9) to achieve thi[illegible] particular objective.

Source: Rothwell and Zegveld (1981)

Table VIII

GOVERNMENT SUPPORT TO THE SEMICONDUCTOR INDUSTRY IN UK, GERMANY, FRANCE AND ITALY, 1964-82[a]

	1967 '68 '69 '70 '71 '72 '73 '74 '75 '76 '77 '78 '79 '80 '81 '82
UK	
(1) Microelectronics support scheme	£10m ($21m)
(2) Component industry scheme[b]	£5m ($10m)
(3) Microelectronics support programme[c]	est. £55m ($111m)
(4) Establishment of INMOS	£50m ($101m)
(5) Microprocessors Application Programme[d]	est. £55m ($111m)
(6) Support to microelectronics under Product and Process Development Scheme	£2.8 (1979) ($0.6m)
(7) Other[e]	annual average: £1-2m ($2-3m)
(8) Military	annual average for '70s (est.) £2-3m ($4-6m)
(9) Non-business institutions and universities	annual average for late '60s & for '70s (est.): £2-3m ($4-6m)
GERMANY[f]	
(10) BMFT (Research & Technology Ministry) support	DM84m ($23m)
(11) BMFT Electronic Component Programme[g]	DM287 ($118m) | DM135m ($74m)
(12) 2nd & 3rd Data Processing Programmes	DM99m ($32m) | n.a.
(13) Synchrotron Radiation Project	DM48m ($76m)
(14) Military and space[h]	DM100m ($33m) | n.a.
(15) German Research Association[h]	DM84m ($22m) (1964-77) | n.a.
FRANCE	
(16) First Plan Calcul[ij]	FF92m ($18m) (1964-70)
(17) Second Plan Calcul[ij]	FF155m ($33m)
(18) Plan Development Circuits Intégrés	FF600m ($132m)
(19) Non-business institutions & government laboratories	annual average (est.): FF155m ($10m) (1965-76) | n.a.
(20) Military	n.a.
ITALY	
(21) Technological Evolution Funds a) grants b) loans	grants L600m ($1m) loans L3.00m ($m)
(22) Electronics Plan (Law 575)[km]	grants L80.000m ($96m) loans L50.000m ($60m)
(23) Military	n.a. (but limited)
(24) National Research Council project on solid state physics	n.a.

Source: Dosi (1981)

Table IX CONSUMPTION* OF NCMTs AS % OF APPARENT CONSUMPTION OF ALL MACHINE TOOLS (in value terms)

	1974	1975	1976	1977	1978
Sweden	10.4	18.0	15.6	19.1	24.5
U.K.	7.3	8.3	8.8	9.7	12.4
Brazil	4.3	n.a.	4.6	3.9	4.9
Argentina	2.8	4.5	4.2	2.4	11.3
Mexico	0.7	n.a.	1.7	2.3	5.1
Taiwan	2.1	n.a.	8.5	6.2	4.5
Rep. of Korea	n.a.	n.a.	12.5	3.8	9.3

*) Please see qualifications from table 2(a).

Sources: Sweden and U.K.: See table 1; For the remaining countries table 2a and American Machinist's yearly data on world consumption of machine tools.

Jacobsson (1979)

Table X

	EXPORT* OF NCMT TO SOME NICs - millions of current US dollars					CONSUMPTION OF NCMTs in U.K. and Sweden millions of current US dollars	
	Argentina	Brazil	Mexico	Taiwan	Rep.of Korea	U.K.	Sweden **
1974	1.5	7.5	1.6	0.9	0.5	37.2	21.2
1975	2.8	26.3	2.4	0.5	6.7	52.7	43.1
1976	3.3	17.8	3.4	3.5	12.5	48.1	32.2
1977	2.4	17.3	2.0	2.7	7.0	58.6	26.9
1978	12.2	22.3	4.6	4.1	22.9	102.5	27.6
1979	9.2	20.8	3.8	10.3	47.1		

*) The data refers to exports from: Japan, US, EEC and Sweden. The data are minimum data as the US trade statistics do not identify more than one type of NCMTs. Also, the Swiss export figures are excluded as are the Swedish figures for 1976. If one assumes that there is no internal production of NCMTs in these NICs, which is not entirely correct but we have not data on that value of production, table 2a and 2b are compatible.

**) The Swedish data excludes specialized machinery such as CNC grinders as these are not identified in the trade statistics. In 1978 Sweden produced CNC grinders, planers etc for roughly 6 million dollars.

Sources: Table 2a. for the EEC data, Eurostat: NIMEXE Analytical tables of foreign trade; For Japan: Japanese Ministry of Trade; For US: US Department of Trade; For Sweden SCB: Sveriges Officiella Statistik: Statistiska meddelanden. Currency conversion rates are from OECD Economic Outlook.

Table 2b. See table 1.

Source: Jacobsson, 1979

Table XII RET R & D FUNDING (1979)

Country		Heating and Cooling	Photo Electric	Thermal Electric	Wind	Ocean	Biomass	Geo-Thermal	TOTAL
Austria	$	1.7	0.4	0.1	0.6		3.3	0.3	6.4
	%	5.4	1.3	0.3	1.8		10.3	0.8	19.9
Belgium	$	1.0	0.8	1.7			0.7	0.3	4.5
	%	1.0	0.8	1.8			0.7	0.3	4.6
Canada	$	8.3	0.8		1.9	0.9	5.6	1.1	18.5
	%	6.0	0.6		1.4	0.6	4.1	0.8	13.3
Denmark	$	0.9			1.8		0.8	5.2	8.6
	%	2.8			6.0		2.5	16.7	27.8
Germany	$	15.6	6.2	7.8	7.6	1.6	1.6	6.0	46.4
	%	1.4	0.6	0.7	0.7	0.2	0.2	0.6	4.4
Greece	$	0.1	0.04	0.4	0.1		0.1	0.3	1.0
	%	2.9	0.9	10.0	2.1		1.5	8.0	25.3
Ireland	$	0.2	0.1		0.1	0.1	0.9		1.3
	%	3.8	2.6		1.8	1.3	18.2		27.7
Italy	$	11.6			0.1			1.7	13.5
	%	5.4			0.1			0.8	6.3
Japan	$	1.3	1.6	14.0	0.3	2.3	0.3	18.7	38.5
	%	0.1	0.2	1.5		0.3		2.0	4.2
Netherlands	$	4.7	1.0		3.9		0.3	0.2	10.0
	%	4.2	0.9		3.5		0.2	0.1	9.0
New Zealand	$	0.2			0.1		0.5	1.5	2.4
	%	2.3			1.7		6.4	18.3	28.6
Norway	$	0.4			0.7	3.4	0.4		4.8
	%	1.0			1.8	8.5	1.0		12.3
Spain	$	1.5	0.6	5.2	0.2		1.0	0.5	9.1
	%	1.9	0.7	6.6	0.3		1.3	0.6	11.4
Sweden	$	15.8		1.1	8.4	0.8	5.6	0.3	32.0
	%	14.8		1.1	7-9	0.8	5.3	0.2	30.0
Switzerland	$	3.6	0.8	1.8	0.04		2.0	0.6	8.8
	%	6.8	1.4	3.6	0.1		3.9	1.1	16.8
UK	$	1.8	0.2		1.1	9.5	1.6	4.9	19.1
	%	0.5			0.3	2.5	0.4	1.3	4.9
US	$	177.6	91.9	94.0	53.8	42.2	27.7	137.0	624.2
	%	4.7	2.4	2.5	1.4	1.1	0.7	3.6	16.5
TOTAL 1979	$	246.2	104.3	126.2	80.8	60.8	52.3	178.5	849.1
	%	3.5	1.5	1.8	1.1	0.9	0.7	2.5	12.0
TOTAL 1978 COUNTRIES	$	143.3	62.7	91.4	48.2	37.1	27.8	112.0	522.4
	%	2.5	1.1	1.6	0.8	0.7	0.5	2.0	9.2
IEA	$								
	%								
EEC	$		21.95				2.52		
	%		44.24		1.4		10.36		

Table XIII Average Increase in RET Funding for IEA Countries between 1978-1979

1. Solar	
a. Heating and Cooling	72%
b. Photo-electric	65%
c. Thermal-electric	38%
2. Wind	69%
3. Ocean	65%
4. Biomass	86%
5. Geothermal	60%
TOTAL	63%

Source: IEA (1980)

Table XIV **Payments Balances on Current Account, Selected Periods in 1971-1980[a]**

	(US $ Billion; Annual Averages) 1971-1973	1974-1977	1978	1979-1980[b]
Developed Countries[c]	+11	-2	+31	-31
Major Oil Exporting Countries	+3	+44	+5	+92
Non-Oil Developing Countries	-9	-34	-36	-62

Sources: Killick, 1981, p.92

Notes:

a - Figures relate to balances on current account excluding public transfers, for IMF members only, thus excluding most centrally planned economies.

b - Forecasts

c - Industrial countries and more developed primary producing countries.

Hoffman (1982)

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Technology Transfer and Export
Marketing Strategies:
The LDC Perspective*

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Technology Transfer and Export Marketing Strategies:

The LDC Perspective

The process of technology diffusion and its impact on socio-economic growth and international trade is of vital concern to multinational corporations (MNC_s), the subsidiairies of such MNC_s based in less developed countries (LDC_s). and the LDC_s and developed countries as economic entities.

The term "technology" has come to include a number of things. Some see technology in the form of patents, licenses, blueprints and trademarks. Others view technology in terms of products, equipment and machinery. Yet others see technology as techniques: advertising, management, manufacturing etc. In fact, technology is a combination of human know-how and equipment. Equipment includes all kinds of tools, machinery, buildings and vehicles, as well as process technology. Technological know-how includes functional skills (including marketing, management and export promotion), information and knowledge about equipment, market know-how, organizational know-how as well as product and process knowledge. Since knowledge itself leads to the creation of machinery as well as further knowledge, it is the decisive factor. Furthermore, since knowledge is held in human beings, technological capacity necessarily calls for increase in the number of human beings with technological know-how as well as improving the knowledge level already possessed by the workers. It should be noted that technological know-how is inappropriate and in many instances useless unless there is a critical mass of knowledge, equipment & market and financial factors. This point will be developed further in the later part of this chapter.

Although much of the media and politial discussion is focused on technology transfer from developed countries to LDC_s, the two proxies for technology transfer - royalties and direct overseas investment, indicate that most technology exchanges occur between developed countries. For example a survey conducted by the United Nations shows that the US in 1968 received a total of $1,246 million in royalties and fees of which only 420 million came from LDC_s. (Basche and Duerr 1975, p.1). Similarly, US direct investment in developing countries, in 1973 amounted to less then 25% of its total overseas investment. (UNCTAD 1981, p.15). A recent study by Mansfield and Romeo indicates that newer technologies go first to developed country subsidiaries followed by LDC subsidiaries and LDC joint ventures. (Caves 1981, p.14).

Our aim in this chapter is to a) establish the critical role of technology imports and diffusion in the economic & developmental transformation of less developed countries (LDC_s); b) establish the role of LDC government in the decision making process in regards to technology acquisition; and c) explore the process and stages of technology diffusion and provide a blueprint for export marketing strategies.

Technological Dependence of LDC_s

The process of technology diffusion is preceeded by technology invention and technical innovation. Because most innovations are labor saving in nature, their payoff is highest for countries with a high value for human time. (The average wage of a skilled worker in five LDC_s was US $0.45 per day in 1975. (Gunder Frank 1981, p.181)). Also an innovation has the highest prospect of success in high income areas where the potential market is large and willing to pay premium price for the new product. Further, in the early stages of production the manufacture is small scale, fluid, somewhat experimental and therefore localized. Therefore, not only most innovations are confined to high income countries*, but also the initial production and consumption occurs in the high income market.

The virtually total dependence of LDC_s on developed countries for technology is a result of several other asymmetries: In education - LDC_s have an overall literacy rate of under 40 percent and a lack of appreciation of technical knowledge; in capital - LDC_s have very limited access to it; they account for 75% of the world's population but only 20 percent of its income; in incentive - there are few benefits to be derived from innovative activities; in skills - there are few opportunities to acquire skills by

* only 6% of the 3.5 million worldwide patents are granted by LDC_s; 84% of these are owned by foreigners.

learning by doing; in means of production - the infrastructure to manufacture capital goods is inadequate. A survey of 128 business leaders of 45 countries indicated a dire need of raising the technological levels of LDC_s and confirmed the dependence of LDC_s on developing nations for the needed know-how (Basche and Duerr 1975, p.1).

The technological dependence of LDC_s has imposed heavy costs on these nations. It is estimated that currently LDC_s pay close to $10,000 million for patent licenses, trade marks, patent know-how and technical services to developed countries each year. (Richardson 1979, p.153). The indirect costs, for example, the overpricing on imports of intermediate goods, mark-ups, and profits on capitalization of technological know-how are probably even higher. Yet, the returns to LDC_s from technology transfers have not been insignificant. National output per capita is a reasonable indicator of the success of technology transfer, since improved productivity and overall output increases are the main consequence of technology acquisition. From 1950 to 1975, the total real output of LDC_s grew at a rate of 5 percent per year (UNCTAD 1981, p.7). This growth rate is higher than the historical growth rate of developed countries and five time the growth rate of LDC_s during the early twentieth century. Another major indicator of technological capability is the domestic manufacture of capital goods. From 1960-75 the manufacture of capital goods in LDC_s was ahead of imports for such goods.

This development is important because it not only reduces the total impact of foreign exchange constraints imposed by heavy costs of technology acquisition but also increases the scope of international trade and economic development. Other indirect and peripheral indicators of technology diffusion ie. fertilizer consumption, per capita energy consumption, number of vehicles in use per 10,000 population and railway freight traffic also indicate a marked growth in LDC_s compared to the rest of the world from the period 1960 to 1976 (UNCTAD 1981, p.16).

Therefore, given the heavy cost of acquiring new technology and the potential for its accrued benefits, it is imperative that economic deveopment of LDC_s be closely coordinated with a well thought-out system and policy of technology acquisition and international trade. This point is developed further in the following pages.

LDC_s: Technology Transfer, Trade and Economic Development

Economic growth results from some combination of labor increase, capital increase, and productivity increase. In LDC_s one-third of the economic growth is attributable to productivity factor as opposed to approximately one-half in the case of developed countries. A recent study indicates that the four semi-industralized LDC_s (Hong Kong, Singapore, Korea and Taiwan) followed a growth pattern that relied heavily on contribution of productivity improvements rather than labor or capital growth. (Chen 1979). This is a particularly significant finding because most LDC_s aspire to model their economies after these four nations and Japan.

Two major sources of productivity increases are technology acquisition and application and economies of scale in production. A third source - improved labour performance may be viewed as a function of successful technological change. It should be noted that technological know-how is the only productivity factor with no natural limits. Thus in the initial stages of industrial development productivity increases result from rising levels of capital and human investment, education, and shift of resources to the more productive industrial sectors, regardless of technological change. However, as the LDC moves closer to limits of such resources, technological improvement is the only recourse remaining untapped and fortunately unlimited in potential.

As indicated earlier, the per capita output of LDC_s grew at a rate of 5% during the period 1950-75. Yet converted into dollars, per capita GDP in 1975, for all LDC_s, was $460 compared to $5,130 in developed countries. Expressed in terms of GDP per labour unit, the comparable figures are $1,230 and $12,290, a ratio of 1 to 10. (UNCTAD 1981, p.19). It has also been estimated that for LDC_s to reach the 1975 level of developed market-economy countries by the year 2000 they need an annual percentage per capita growth rate of 10.1 percent. (UNCTAD 1981, p.21). Can a technological chasm of this

size be overcome? The Japanese experience in the 1950s and 1960s indicates that technology gaps can be effectively narrowed by the diffusion process leading to economic development. From 1950 to 1971 Japan spent close to $3 billion on technology acquisition and presently she enjoys the highest sustained rate of productivity increase. However, the crucial factor that allows the productivity increases to be translated into economic devleopment is a sustained growth in exports. This is particularly true for non-OPEC LDC_s with large oil imports and rising debt service charges. It has been estimated that from period 1971-81 LDC debt charges have increased at an annual rate of 26 percent - from $11 billion in 1971 to $112 billion in 1981. On the other hand the external debt of LDC_s increased by only 20 percent over the same period (OECD Observer 1981, p.7). Also over the period 1970-1980, for all LDC_s the ratio of net fuel imports as a percent of total exports increased from 9.1 to 28.7 (Wallich 1981, p.21). In countries like India, at the present time close to 50 percent of export earnings are absorbed by oil imports. When debt service charges are added to oil imports, by the year 2000, 80 percent of export earnings will be absorbed by these two obligations for all non-OPEC LDC_s. However, such a pessimistic projection may be proven wrong if external markets are opened further to LDC_s and trade barriers and quotas substantially diminished leading to vigorous trade, and (given the recent breakthough in energy efficient products) emphasis is placed on importing up-to-date technologies.

In the 1960s and early 1970s OECD countries experienced rapid economic growth and world trade grew almost twice as fast as industrial production (IP). Presently the world trade is growing at approximately the same rate as IP and the picture is one of general economic slump in all three trade zone - the U.S., Europe and Japan (Chase Manhattan 1979, p.96). The dynamic growth of a number of LDC_s in the last few years resulted from abundent labor, technology availability and access to economically vigorous OECD markets. In 1978, as a group, OECD member countries imported approximately 10 billion dollars worth of electrical appliances and machinery from LDC_s (OECD 1981, p.4). It is clear from table 1 that although there is a trend toward greater imports from LDC_s, their share in the total import of all manufacture is merely 10.1 percent. Further, imports from LDC_s are dominated by a few

Table 1

Share of Imports From LDC_s in Total OECD

Imports of Manufactures

(%)

	1970	1976	1977	1978	1979
Chemicals	4.5	3.9	4.1	3.2	4.1
Iron and steel	2.9	4.3	4.2	4.6	5.5
Textiles	13.0	17.1	17.0	19.8	20.5
Clothing	27.4	44.0	42.8	45.5	44.7
Footwear, leather goods and furs	16.4	31.9	31.6	34.5	33.9
Non-electrical machinery	0.8	2.2	2.4	2.7	2.9
Electrical machinery and appliances	5.3	12.6	13.2	15.4	17.2
Road motor vehicles	0.2	0.6	0.6	1.1	1.1
Other transport equipment	2.0	3.9	5.3	8.2	5.5
Other manufactures	6.8	9.5	10.3	11.1	11.1
All manufactures	5.3	8.7	9.0	9.9	10.1

Reprinted from OECD observer, March 1981, No. 109, p. 7

countries only - particularly Taiwan, Hong Kong and Singapore. In 1970, for example, while imports of manufactures from these three nations were in excess of $10 billion each, Mexico, India, Israel and Yugoslavia traded below the $4 billion mark (OECD 1981, p.7).

In view the tremendous financial drain on LDC_s resulting from oil payments, debt service charges and purchase of capital goods, it is imperative that OECD and other external markets remain open to them. Although the Ottawa Summit of OECD governments' pledge to further open their markets to LDC_s is a welcome sign, a concerted effort on the part of these nations is needed to collaborate in the areas of economic and technological assistance. In the years to come, it is critical for LDC_s to make at least substantial progress toward improvement of their system and policy of technology acquisition and diffusion and international trade infrastructure - particularly in the area of export market strategies.

Technology Import Options

At the present time there is no generally accepted indicator of technology transfer. However, transfer of technology is believed to be strongly related to LDC imports of machinery, their payments for technical services and licenses, and direct foreign investment in LDC_s.

From 1970-79, there was a 10% (real terms) yearly growth in OECD world exports of machinery and equipment to LDC_s. This represented over 40% of total OECD exports in the area of machinery and equipment. During the same period payment for licenses, technical and commercial services increased by 4% each year (in real terms). The third indicator of technology transfer, direct foreign investment, increased at approximately 3.9% per year (in real terms). Financial flows, another indicator of technology transfer, increased substantially during this period. Borrowing by LDC_s increased at an annual rate of 10% (in real terms) during the period. It has been estimated that the US, Japan, France, UK and Germany supply approximately 70% of the technology imported by LDC_s. (OECD 1981, p.5). The following discussion deals with different means of technology transfer.

Licensing Agreements. These are agreements whereby the licensor provides know-how, copyrights, patents or trademarks in return for royalties, a percentage of sales or profits, or a lump-sum fee. In most cases the licensor does not cede property rights; it merely provides specific rights of use of a given technological know-how. International franchising is an example of licensing agreement whereby the technology bundle provides know-how, trademark, training programs, and geographical monopoly.

Joint Ventures. Two types of joint ventures are common in developing countries. First, those where equity is held more or less half-and-half by the LDC based partner(s) and the multinational corporation(s). The exact distribution of shares maybe determined by each partner's contribution in the

areas of technology, capital, machinery, managerial skills etc. And second those that involve more than one LDC in the technology transfer agreement.

Joint ventures are preferred by countries with the basic infrastructure of management and production because they normally lead to sharing of profits, assets, risks and most important of all, technology. Such agreements are particularly appealing when they involve the so called phase-out clause. Under such a clause it is agreed that over a specified period of time ownership will gradually be transferred to the LDC partner. Thereafter, the MNC partner may function as a consultant, minority stockholder, or simply draw a fixed royalty. International marketing is one area where the MNC partner is likely to be actively involved even after the phase-out is complete. Joint ventures have been the cornerstone of India's commercial developmental program because of the long-run economic and political appeal of such agreements.

Turnkey Operations. Under such product-in-hand agreements the supplier is usually responsible for completely installing and operationalizing a given industrial complex. The first turnkey agreements appeared in the early 1960s and were being used by only a small number of LDC_s toward the end of the decade. The late 1970s brought a resurgence of turnkey agreements mainly due to the vast recycling of petro-dollars through large contracts by OPEC countries for industrial plants.

<u>Training and Development Contracts</u>. These agreements call for the MNC to provide training for local personnel when need arises due to advances in learning in any of the areas of operation. Such contracts maybe modified in the following two ways. First, training of local personnel maybe part of a larger package of a management contract. In this case, the MNC initially provides a complete package of management functions including planning, organizing, directing, controlling, motivating and maintaining a viable training and development program. Gradually, the management authority is handed-over to the LDC country personnel. In some cases, the LDC party may wish to retain the MNC party as an independent observer to monitor the performance of the new enterprise for a specified period of time. Second, training of local personnel maybe a part of a multiparty contract package whereby one or more other groups (from an LDC or IC) are providing plant and machinery, capital, technology etc. Such multiparty contracts may also take the form of subcontracting, particularly for turnkey projects.

<u>International Sub-contracting</u>. This usually involves, a MNC based in a developed country that contracts one or more firms in one or more LDC_s to manufacture parts or assemble them. All inputs are provided by the MNC and it retains all marketing rights - in the LDC_s as well as the MNC home country.

<u>Multiparty Industrial Co-operation Agreements</u>. Under such agreements three or more parties get together to perform a project in a LDC. A major difference between such agreements and multiparty contracts discussed above is that in the former case one or more parties represent communist-bloc economies in addition to one or more MNC from a developed country and one or more parties from the host LDC. Such agreements often take place on a turnkey basis. The parties representing the centrally planned economies usually provide equipment, low-technology, and skilled labour. The Western MNC_s usually contribute high-technology and electronic equipment and LDC partner provides raw materials and engineering skills for the construction of the plant.

<u>The Role of Government</u>

Technology diffusion does not take place in a vacuum. Transfer of know-how occurs effectively when specific government policies encourage research and educational programs in related areas of finance, administration, and international economics.

A review of governmental policy framework in regard to technology transfer indicates that no systematic steps have been taken by most LDC_s to promote such transfers. It should be noted that although several developing country governments offer help in the form of tax incentives to attract foreign investment, technical and financial assistance, investment insurance, and establishment of central development corporations, there is a underlying lack of coordination among the objectives of various measures. Furthermore, there is no indication that such objectives indeed complement the priorities of LDC_s.

A healthy assimilation of foreign know-how is first and foremost conditional upon a societal climate of receptivity to new ideas. Strong measures are needed in LDC_s, particularly India, Pakistan, and most African nations, to foster interest in invention and innovation. Such measures could include village extension programs, TV and radio shows, modifications of primary school curricula and establishment of centers for the promotion of invention and innovation. The multitudes of engineering colleges in India, should promote a curriculum that highlights the developmental benefits of technology assimilation. Further, such engineering and technical colleges could provide consulting service to the community on a regional basis.

Next, to encourage innovative diffusion of technology there must be present a strong package of financial and non-financial incentives. Patent protection, provision of risk capital, soft taxes on profits and capital gains and adequate financial stipends will go a long way in encouraging a potential entrepreneur. Such incentives should be available to both individuals and organizations. Steps must also be taken to create an atmosphere whereby it becomes desirable for financial institutions to provide risk capital.

On the government side, there is great need for developing the capacity for meaningfully evaluating various technology options (discussed earlier), assessing various sources (including domestic) of supply and negotiating for maximum benefits and least costs for the import of a technology. In the cost-benefit analysis critical considerations include appropriateness* of the new technology and potential for local diffusion. Myopic and emotional actions, such as defensive import substitution are not technologically progressive and likely to be unsuccessful in the long run.

It should be noted that although by the mid 1970s advanced LDC_s (ie. Mexico, India, Brazil, S. Korea, and Philippines) had significantly improved their position as technology importers (through the formation of technology transfer centers, industrial property institutes, foreign investment legislations, technology transfer pacts etc.) three major inadequacies remain. One, although most of these countries (particularly India), have a variety of research and development organizations, the vital link between technology imports and its local promotion and diffusion is largely unexplored and ineffective. Two, with regard to the technology acquisition process, there is little or not coordination between various groups and

* An appropriate technology maybe defined as one which utilizes domestic inputs to the greatest extent, satisfies local consumption needs, is non-threatening to the domestic socio-cultural system, and has the least negative environmental impact.

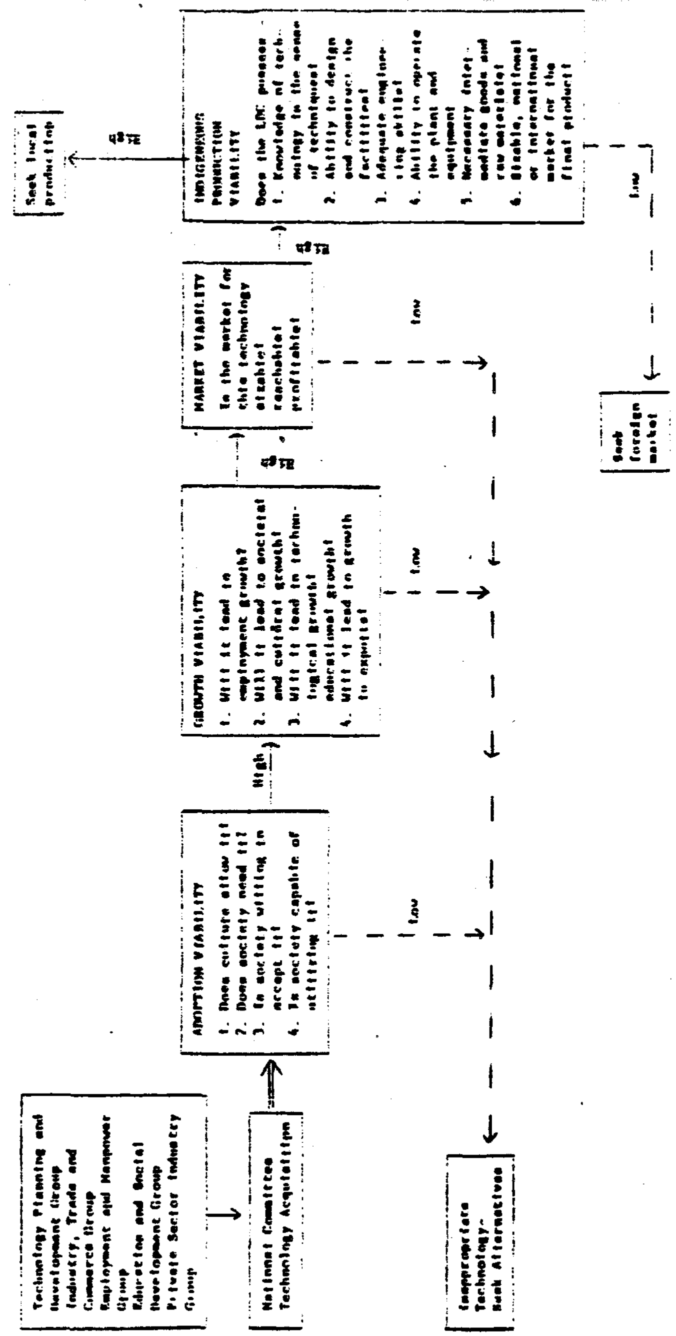
organizations that are directly or indirectly knowledgeable about and affected by a given technology transfer. And three, the actual framework fo determining the appropriateness of a technology acquisition is inadequate c: lacking.

Figure 1 envisions a national decision-making committee composed of representatives of various groups involved with technology acquisition. To determine the suitability of acquiring a certain technology, the committee systematically explores the possibility of local acceptance of the new technology - its impact on domestic economic, socio-cultural and educational growth, the profitability of the domestic market and endogenous production potential. If either adoption, growth or market viabilities are low, the technology in question is inappropriate and alternatives must be sought. On the other hand, if all three viabilities are high, the committee explores the possibility of local production leading to the final outcome of either acquisition from foreign sources or domestic production. As indicated earlier a number of LDC_s have developed policy measures to deal with the transfer of technology: the above scheme provides a framework for coordinating the objectives underlying the various policy initiatives and matching indigeneous needs with such measures.

<u>Process of Aggregate of Technology Diffusion/Adoption</u>

Figure 2 develops a paradigm to illustrate factors that encourage /retard the domestic aggregate diffusion of a new technology. The

FIGURE #1 TECHNOLOGY ACQUISITION DECISION PROCESS



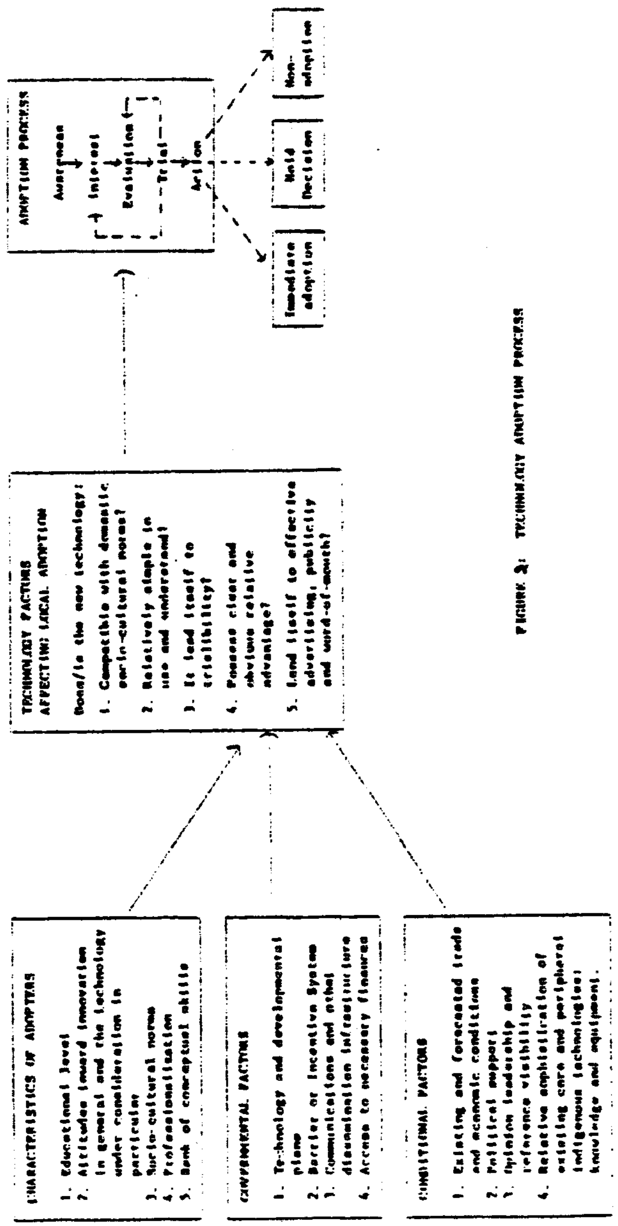


FIGURE 2: TECHNOLOGY ADOPTION PROCESS

environment affecting the rate of diffusion is divided into three groupings: governmental factors, conditional factors and adopter characteristics. Each of these groups in turn affect the answer to five critical questions relating to the new technology. The more change a new technology requires in the existing socio-cultural norms and patterns of behaviour the greater is the resistance to its adoption. If the new technology is clearly advantageous in terms of expected profits, it will be adopted sooner. Also, the easier it is to understand, relate to and explain the new technology the higher will be the rate of adoption. The more a new technology lends itself to trialibility, sampling etc. the less will be the perceived risk and the extent of commitment and therefore higher will be the rate of adoption. And finally the degree to which the benefits of the new technology can be effectively displayed or demonstrated will enhance the rate of adoption. The actual adoption process - awareness, interest, evaluation, trial and action - is therefore highly influenced by the conditions relating to the imported technology. Generally, impersonal mass media devices are more effective during the awareness, interest and often evaluation stages; the later stages benefit more from word-of-mouth, and local face-to-face encounters with information disseminators.

The distribution of enterprises over time, that adopt a given technology, will follow the bell shaped curve shown in figure 3. Normally a few highly innovative and risk prone enterprises adopt at first, rapidly followed by others. Figure 3 indicates that the rate finally diminishes as only a few potential adopters are left in the nonadopter category. Innovators are defined as the first 2.5% of businesses or individuals to adopt the innovation; laggards are the final 16% to adopt. Next section of this chapter explores the technology diffusion process within a individual firm and makes recommendations for export strategies at various stages of the process.

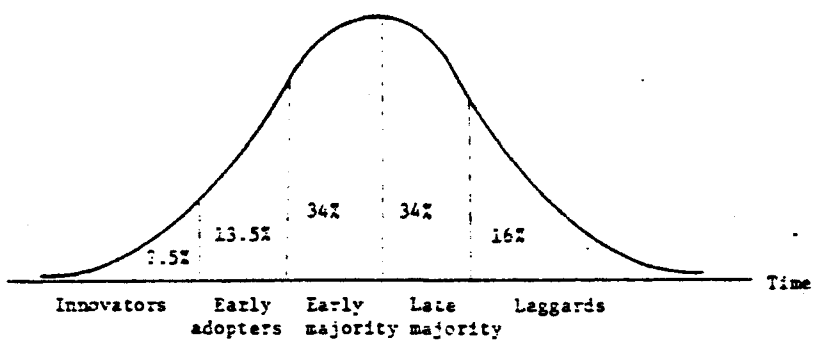


Fig. 3 Adoption Curve

Intra-Firm Techonology Diffusion and Export Marketing Strategies

Technology diffusion at the level of a individual firm has received little emphasis from researchers. One reason for this is that while most models of diffusion are based on the concept of productive efficiency, the core of the litterature in the area deals with life cycle of new products. In other words, the Product Life Cycle Theory provides limited guidance in the way of empirical research when technology is understood to include equipment such as tools and machinery as well as know-how in various functional, organizational and information areas. (see p. 1 for details). Secondly, while the PLC theory, as represented by the works of Vernon (1966) and Wells (1972) is an innovative extension of the earlier works of marketing researchers* it ignore the significance of marketing variables like promotion and product differentiation for export development. In other words, two products that are similarly in the maturity stage of the PLC are likely to show different export potential because of their differences from a marketing perspective. Although some researchers, notably Findlay (1978), de la Torre (1972) and Krugman (1979) have provided useful insights into the two issues, two specific questions remain unanswered.

* For an excellent discussion on PLC research in marketing see Buzzell (1966, pp.46-64), Cox (1967, pp.375-384), Levitt (1965, pp.81-94), Polli and Cook (1969, pp.385-400), and Wasson (1968, pp.36-43).

What is the typical pattern of technology assimilation* within an LDC based firm? At what point in the diffusion process is the local firm ready to take over critical market and product design decisions, promotion and pricing decisions, export decisions?

In order to answer the first question the following hypothesis was formulated: the learning curve for a firm assimilating a new technology is non-linear and has the characteristic shape shown in figure 4. The theoretical basis for this hypothesis was consolidated by surveying about ninety-five experienced technical managers of a consumer electronics industry in a LDC. The survey was accomplished by open-ended personal and telephone interviews administered over a period of four months in 1978. The survey sought the subjective opinions and perceptions of these managers on matters involving productivity change over time, relative success of employee training and development programs, competitive environment, technical information flow, governmental and political influence, and export marketing problems and opportunities. In addition to providing the theoretical basis for the above hypothesis, the interviews provided critical insights into the question of appropriate export marketing strategies at various stages of technology assimilation.

* Technology assimilation should be viewed here as the embodiment of functional knowledge by the company personnel.

Based on the information obtained, four stages of technology assimilation were identified, namely 1) Do-how stage; 2) Do-why stage; 3) Know-how stage; 4) Know-why stage. Each stage was found to be characterized by a gradual internalization of activities and decisions that had been performed earlier by the MNC. In an earlier study (Kindra and Goyal 1981) the hypothesized shape of the diffusion curve was operationalized and tested. The study using data relating to a Canadian MNC and its operations in a LDC over a 10 year period tentatively confirmed the shape of the hypothesized learning curve shown in figure 4.

It should be noted that the firm's learning curve embraces more than individual learning by repetition of a work task; it describes a more complete organism - namely the collective adsorption of knowledge of many people, all striving to perform common tasks with increasing efficiency.

We will describe the four technology-asimilation stages and then discuss the strategic options open to LDC export firms at each stage.

Table 2 schematically presents the four stages of technology assimilation and how they relate to the familiar marketing strategy variables of product, price, promotion, distribution, and post-purchase service. The exhibit shows the degree to which various responsibilities within the marketing strategy areas fall on the company in the various stages of technology diffusion. These relationships were identified on the basis of above-mentioned interviews and studies of various case histories.

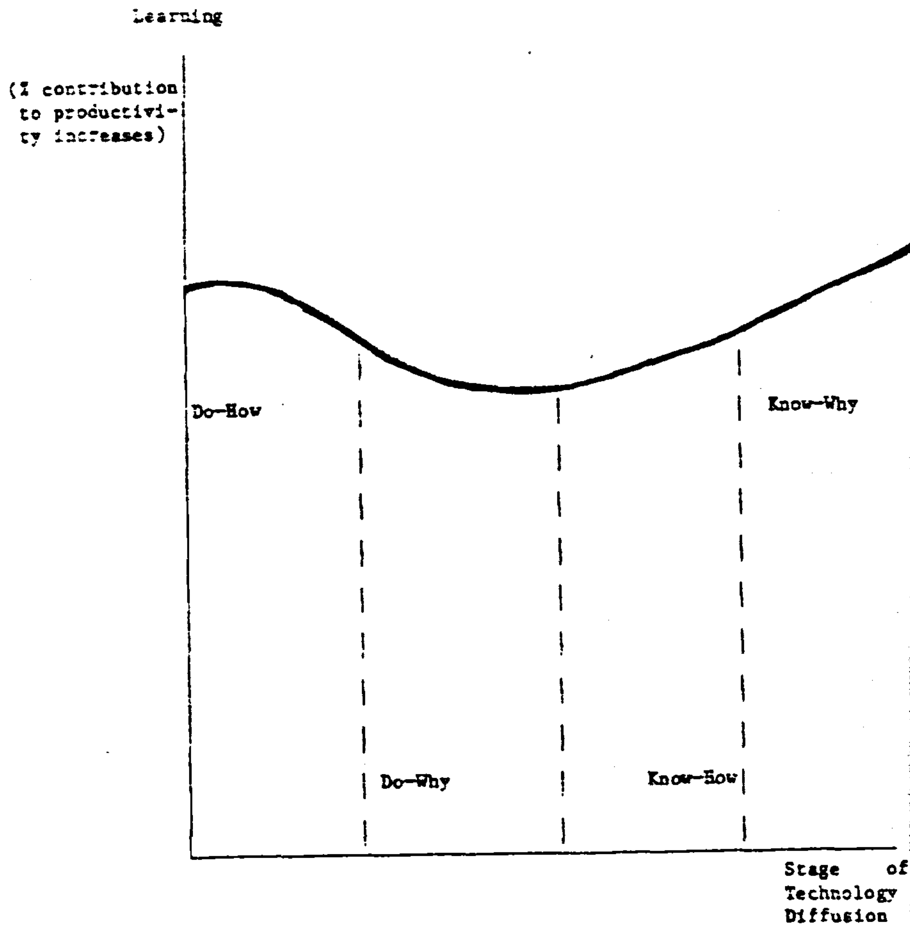


Fig. 4. Diffusion Curve of a firm in LDC.

Table 2

Stages of Exports Market Development

	Product			Price			Promotion			Distribution		Post Purchase Service		
	Core-Product Decision	Augmented Product Decision	Quality Control	Price to Retailer	Price to Consumer	Local	To Importers	To Retailers	To Consumers	To Retailers	To Distributors	Warranty & Guaranty	Missionary Selling	Marketing Research
Do-how	1	0	0	0	0	1	0	0	0	0	0	0	0	1
Do-why	2	1	1	0	0	1	1	0	0	0	0	1	1	1
Know-how	2	1	1	1	1	2	1	1	0	1	1	1	1	1
Know-why	2	2	2	2	1	2	2	2	1	1	2	2	1	2

0 = No Involvement
1 = Partial Responsibility
2 = Full Responsibility

Do-how Stage. During this phase, the employees of the firm become familiar with the basic skills; for example fitting, turning and milling skills in the machine tool industry. In the case of product technologies, manpower will progressively become familiar with assembly operations. In process technologies (such as fertilizer plants), the people become familiar with the operating characteristics of the process. The important requirements of skilled people in this stage will be to handle different jobs and perform multiple functions. This stage provides the groundwork for further assimilation; hence the need to have a strong foundation cannot be overemphasized.

During this stage, the firm is in no position to seek exports. Their export business, if any, is initiated by a MNC searching for a low cost production facility. The firm at this stage typically lacks the skill and the market and product know-how to make independent export decisions. In almost all cases, the local producer in this stage is merely a seller of production capacity.

Do-why Stage. The local company usually evolves into the second stage - particularly when the technology is new, complex, and guarded. On the other hand, when the technology in question is simple, time-tested, and easily accessible, a company may begin operations in the second stage.

During this stage, skilled people develop their skills further mostly by learning by doing. Technical personnel also acquire specialized knowledge of certain key aspects of the manufacturing process especially in the area of critical inputs and distributor relations. In this stage, the company tries to reduce its dependence on the "imported" technology and usually identifies local suppliers and/or simpler endogenous manufacturing processes. Another important feature at this stage is the attempt at diversification of product range by minor modifications such as adaptation of a two-speed lathe to a three-speed lathe in a machine tool firm.

At this stage, the firm is in a position to exhibit samples, organize a basic marketing department and make attempts to move into the export arena. Such attempts will typically include contacting importers by mail, getting listed in the relevant trade directories, calling on importers visiting the LDC and to some degree participating in trade shows and exhibitions in the importing countries.

Trained personnel by now have acquired skills to train others and the firm is self-sufficient in operating skills.

Know-how Stage. At this point, the firm focuses on development from within although assimilation of technology is still taking place in the areas of design, packaging, quality control, and promotional subtleties. Product modifications at this stage are the "product to product" type as, for example, making the product of better quality or redesigning and manufacturing similar products capable of satisfying additional consumer needs. These modifications result from learning by research applied to specific problems. By this time the technical base of the local environment is sufficiently geared to provide the services required by the firm. Reliable suppliers of standard parts and anciliiaries for intermediate inputs are established or identified. Further, both suppliers and manufacturer have become quality conscious toward the product. Quality consciousness is reinforced by the consumers, thereby setting the pace for technological improvements.

At this stage, we have a marketer of products and not a seller of production capacity. In the clothing industry, a firm at this stage will start to take full responsibility of design, create its own brand names, ship goods directly to their destination and get conscious of its marketing deficiencies. The main tool of competition in the clothing industry at this stage, is quality control and efficient distribution. Whereas in the consumer electronics and shoes, it is still price. The leaders of the industry at this stage start to emphasize "pull" based marketing strategies in order to command premium prices.

LDC-based firms at this stage have access to many of the style changes and technological advances taking place at the MNCs. However, except a few

leaders in the industry, adoption of these innovations is restrictive - mainly due to an incomplete grasp of marketing factors, and the absence of sophisticated strategic planning. From this stage onwards, the firm needs to take a multidisciplinary approach to development and diversification, i.e., it must invest in related areas of science and technology. A machine tool company, for example, draws heavily from the fields of electronics, aeronautics, hydraulics, and space technology and must keep abreast of the developments in these areas.

Know-why Stage. This transformation from the third stage to the fourth is most difficult to achieve. This transformation is brought about through a slow and evolving process to which contributions of academic institutions, government and the firm are equally important. Learning by research is a risky endeavour in this stage, since the outcome is more uncertain then in the know-how stage where research is more specific than fundamental. The main functions of learning by research in this phase are:

a) To Translate a Concept into Products. An example would be to convert the concept of non-cutting metal removal process to an electro-chemical machine.

b) To Use the Same Product for Different Concepts or Applications. An example would be the adoption of electronic controls developed for computers as control systems for machine tools.

Very few firms in LDC's will reach this stage affecting such major transformations. However, the Japanese experience indicates that firms in this stage will become indistinguishable from the MNCs in the importing countries. At this stage the circle has gone a full turn from a "push" based, production capacity to "pull" oriented consumer franchise. A company at this stage will organize a sophisticated marketing research department and employ advertising agencies and other services much as the importing firms do.

Not all firms strive for this stage; neither may it be desirable. Many firms (particularly the small ones) are content to follow the leader. Others, discouraged by the heavy financial requirements (particularly in the capital intensive industries) may concentrate only on selected areas and "purchase" technology improvements from the more adventurous firms.

Strategic Options for LDC Exporters. The following strategy options will be discussed from the perspective of an individual firm. We will, for example, not concern our analysis with the politically colored goals of the government, such as macroeconomic development and fair allocation of scarce resources to different industrial sectors.

From the perspective of LDC firms, the evolution from do-how to know-how stage is clearly attractive because it places the firm in a position to command large profits based on its unique skills (rather than merely

production capacity). The resources invested in efforts to acquire such skills is quickly mitigated by the intraorganization diffusion of know-how. It is, however, not clear whether a move to the know-why stage is always desirable. Know-why stage requires heavy investment, major structural changes, and strong credit support from govermental as well as non-governmental sources. In general, an ability to face high risk and absorb major losses is a major prerequisite for entry into the know-why stage.

It is at the know-how stage that the firm faces the option of either foregoing short-run profits and concentrating on the long-run success of standardized products, or paying greater attention to expansion and/or improvement of the present product line. The latter strategy works best when large retail outlet in the importing country can and will buy directly from the producer. On the other hand, the former strategy will require the producer to proceed to the know-why stage - particularly when the market is dominated by "middlemen" that threaten to cut off the stage III firm's access to the retailers. The Indian ready-made garment export industry is presently faced with a similar decision. In the face of increasing number of dominant import houses, the stage III exporters are being forced to open overseas marketing offices and showrooms, establish and maintain contact with retailers, and perform a full range of promotional and post-purchase maintenance activities.

A vast majority of the stage I - III firms in the garment export industry in India rely extensively on the letter of credit (LC_s) to bolster their working capital. The know-why stage firm essentially loses the LC facility because it delivers goods directly to its branch office in the importing country where the products will be offered at whatever terms exist at that time. Without the LC "benefit", and in the absence of strong financial support, either from within or outside the firm, many stage III firms could not take on the risk of financing work in process, and maintaining viable promotional, products handling and distribution systems, thereby significantly reducing the changes of their entry into the know-why stage.

It should be noted that in the case of high technology-based products like computers and calculators, the problems of the know-how stage firm, trying to enter the know-why stage, are even more acute because relative to clothing: 1) calculators and computers are high-priced items, 2) establishment of a strong national brand name is necessary, and 3) very heavy R and D expenditures are required. It is specifically because of these reasons that the government-runned Hindustan Machine and Tools (HMT), despite strong efforts, has failed to establish itself as stage IV exporter of wrist watches. To cite another instance in 1970, the know-how stage firms of Italy and West Germany controlled over 34% of the world calculator market.

However, with the Japanese firms' successful and forceful entry into the know-why stage in 1968-69 and the consequent reluctance of large retailers as well as consumers in buying "no name" Italian/West German calculators and the inability of Italian/West German firms to enter the know-why stage because of poor marketing/financial backing, their combined share of the world market declined to 1% in 1977 (US Department of Commerce, 1966-77).

Since the know-why stage consumes large amounts of precious foreign exchange, the governments of LDC_s are generally reluctant to provide grants/loans which may be "better" spent on, for example, agricultural machinery.

To summarize, the know-why stage entry may be unnecessary when most of the following conditions exist:

a) The nature of the product is such that it is low cost and relatively standardized.

b) No competitor exists in or plans to enter the know-why stage in the forseeable future.

c) The technological base is stable and not complex.

d) Marketing conditions and nature of the product do not require strong brand positioning.

e) Links with major retailers are strong and mature.

Alternatively, when most of the above conditions are absent, a firm may have no choice but to make an eventual move to the know-why stage. Without a strong financial, marketing, and entrepreneurial backup, the move to stage IV is likely to be unsuccessful. One alternative to this fatal push into the know-why stage is to attempt persisting in the know-why stage by specializing in and catering to the low-priced market. A manufacturer of stereo equipment, for example, can last in the know-how stage by maintaining the position as the "lowest" cost supplier in the industry. Once this distinction is lost, the firm must either move to stage IV and attempt to establish a national brand name or eventually perish.

At least three topics, touched upon this section, need to be developed further. One is the nature of the relationship between the goals of a LDC and LDC firm; two, relationship between market structure and strategic alternatives; and three, an assessment of alternative strategies purely form a LDC governmental perspective.

Summary, Conclusions and Future Research

Section 1 of this chapter established the fact that LDC_s are heavily dependent for their technology needs on industrially advanced nations. Reasons include asymmetries in the areas of education, skills, incentives, and production infrastructure. Section 2 explored the impact of technology transfer on the trade and economic development patterns of LDC_s. It was

concluded that given the large payments for oil imports and debt service charges, LDC_s must continue to seek international trade vigorously for economic development. Section 3 sought the various technology import options available to LDC_s. Section 4 dealt with the question of technology appropriateness and provided a decision making framework in regards to technology acquisition. It was concluded that an overall planning procedure for technology acquisition is an integral component of national development efforts on the part of LDC_s. Section 5 provided a paradigm to illustrate various factors that encourage/retard the domestic diffusion of a new technology. It was suggested that the speed with which an individual firm adopts an innovation is strongly influenced by technology characteristics like compatibility with socio-cultural norms, degree of sophistication of the new technology, the obviousness of its relative advantage, inherent communicability of the acquired technology, and the degree to which it can be tried before the final decision to acquire. The last section dealt with the diffusion of technology within a LDC based firm and provided a case study that tentatively established and explored various stages in the diffusion process. This section also provided a rudimentry blueprint for export marketing strategies for local firms at each stage in the diffusion process.

Several topics touched upon in this chapter need to be developed further. As indicated at the end of section six the nature of the relationship between LDC goals and LDC based firms' goals, as well as an assessment of alternative export strategies from a purely governmental perspective are areas that need to be further explored. The possibility of cooperation by firms within various LDC_s as well as the viability of establishing a "technology bank"* operated by and for LDC_s needs to be researched. Several manifestations of the concept of LDC_s "technology bank" maybe to provide such nations with some control over their technology imports, strengthen their negotiating capacity, ensure a certain degree of technology appropriateness and reduce duplication of technology imports by member LDC_s - thereby making such acquisitions more affordable. There is also a need for a comprehensive study on the role of small and medium firms in technology diffusion and exports promotion. And finally, the question of how economic and technological aid from the industrialized nations can be funneled toward a viable trade and development policy needs to be explored indepth.

Over the next two decades LDC_s will experience upheavals similiar in magnitude to the ones experienced by the West during the Industrial Revolution. It is in anticiaption of such transformations that LDC_s must

* The term "technology bank", in this context refers to a regional organization, specializing in the accumulation of technological capacity (in the form of know-how, blueprints, patents, equipment, and trained manpower) and its orderly flow to contributing member nations.

give top priority to developing the capacity to import. diffuse and invent technologies and relate the same to trade and development policies and programs.

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MOD 13

"MINERAL LEACHING BY BACTERIAL METHODS IN DEVELOPING COUNTRIES AND THE IMPLICATIONS FOR POLICY WITH PARTICULAR REFERENCE TO THE ANDEAN PACT COPPER PROJECT"

Alyson Warhurst

The minerals industry at present is having to take account of economic and environmental considerations such as the depletion of reserves and the decline of ore grades, stricter pollution regulations and rising investment and energy costs - all in the context of low and unstable metal prices.

Technical developments in the minerals industry over the last decade in response to these factors mean that there now exist a number of technically viable options to be considered during process route selection. These technical changes are also opening up the way for the economic recovery and extraction of metals from mineral resources previously unutilized. Recent innovations in pyrometallurgy include: matte-making processes such as flash furnaces, oxygen sprinkling smelters and electric furnace smelting, and continuous matte-making and converting techniques like the Noranda and Mitsubishi processes. In the area of hydrometallurgy, processes for leaching sulphide minerals and mixed ores using chloride, cyanide, ammoniacal and bacterially activated solutions, have been developed.

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mineral content and, in so doing, preventing natural pollution by uncontrolled acidic effluents.
Secondly, the leaching of overburden from newly developed mineral deposits, and of marginal ore during ongoing operations, in heaps specifically designed to optimise the leaching process for short term economic gain.
Thirdly, the more novel possibility of leaching sulphide concentrates in confined systems under carefully controlled conditions.

These developments have important implications for mineral producing developing countries, not least with respect to technical choice and decision making, since the majority of sulphide porphyry deposits are located within their boundaries. Many of these countries, including Argentina, Brazil, Bolivia, Chile, Colombia, Ecuador, Indonesia, Panama, Papua New Guinea, The Philippines and Peru, are now embarking upon process route selection for new mineral projects. Bacterial leaching technology could be considered in many of them.

Indeed, in Chile bacterial leaching technology development is one of CODELCO's most important planned investments for next year. Impressive projects are in progress at Chuquicamata, El Teniente and Salvador. Exxon is also planning a huge heap leaching project for the marginal overburden to be removed during the development of its large porphyry deposit at Los Bronces. In Peru, bacterial leaching is planned to play an important economic role at Toromocho (CENTROMIN), Cerro Verde (MINEROPERU), and Pativilca (HORSCHILD). Similar projects are being considered by RTZ at Cerro Colorado in Panama, by COMIBOL at Tasna in Bolivia and by Colombia, Argentina and India.

However, virtually all the examples of the commercial applications of this technology are to dumps of previously considered waste or marginal ore and are mainly located in the industrialised countries (e.g. S.W. USA, Canada and the USSR). Since it has only recently been realised that sulphide leaching has a microbiological component, these dumps were not constructed according to parameters to optimise the process. So although these bacterial leaching operations account for over 10% of the production of US copper, they generally have recuperation rates no higher than 40% of the contained metal in a period of about five years.

In optimal conditions Theobacillus ferro-oxidans and others, besides acting directly on the minerals, accelerate the oxidation and dissolution of sulphide minerals in a ferric sulphate and sulphuric acid medium by up to 10^6. However, being living organisms they have various requirements for optimal growth (and thus optimal leaching rates). These include a highly acid PH, high oxygen availability, nutrients, a warm temperature range, etc. Optimization can proceed along three main routes - leach system design, solution management, and bacterial growth and yield - and can achieve recuperation rates of 80% in time periods of 18 months to three years.

For example, if the heaps are too large their centres may be starved of oxygen and temperatures in the core may rise due to the oxidation of the pyrite. This makes the environment inhospitable for bacteria and thus reduces the leaching of the contained mineral content. Similarly, if the ore decrepitates easily, fines will be formed which in turn constrain leaching reactions. The consequent rise in PH reduces bacterial activity both directly and indirectly - by causing iron salts to precipitate, coating mineral particles and leaving them inaccessible to attack.

Thus, heaps could be built lower and longer, i.e. as finger dumps; control checks on the recirculating lixiviant could be carried out; bacteria could be reinnoculated into the solution, and nutrients added, etc.

However, the rock type and its natural particle size after dynamiting will determine the necessity for preliminary crushing, the addition of extra acid or the special design of finger dumps; the hydrogeology and soil types of the location of the leaching operation will determine the need for prior ground surface preparation; and the availability and characteristics of local acidic minewater and vibrant indigenous bacteria will ultimately determine the efficiency of bacterial leaching for a given location.

Thus, the cost structure of optimising a bacterial leaching project is highly dependent upon the geology of the mine location.

The principal implication of all this is that there exists no precedent in the indistrialised countries of optimised bacterial leaching operations. There are no general models upon which the developing countries can design their leaching projects, and, as a source of technology transfer, the potential of the industrialised countries is limited. Although, it should be added that throughout the last year applied R&D in the area of the bacterial leaching of the main sulphide minerals has been receiving an increasingly large investment by firms, institutes, universities and international technical and financial assistance organisations (OEA, UNIDO, UNEP, etc.).

It is within this overall context that the Andean Pact Copper Project has been the subject of detailed fieldwork. It represents one of the few examples of the development and application of bacterial leaching technology within the developing countries.[1/] In addition to its intrinsic importance, it is also interesting since it was designed to achieve technology policy goals. These included the development of local facilities and skills and a more efficient system of technology transfer both from developed countries and between developing countries.

The specific objectives of the Copper Project were:[2/]

(1) To form teams of people capable of managing efficiently the hydrometallurgical technology of copper from the laboratory level up to the

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1/ The Cananea bacterial leaching operation in northern Mexico is the only other known application.

2/ Junta del Acuerdo de Cartagena, "Proyectos Andinos de Desarrollo Tecnológico en el Area de la Hidrometalurgia del Cobre". J/GT/12, 2 Sept. 1974.
Ibid., "Proyectos Andinos de Desarrollo en el Area de la Hidrometalurgia del Cobre". (Decisiones 86 y 87 de la Comisión del Acuerdo de Cartagena) J/GT/16/Rev. 1, 12 Jun. 1975. Direct translation from the Spanish.

design, construction and operation of industrial plants. The people should be left capable to continue R & D work and to perfect, adapt or design new technologies based on the knowledge transferred through the project.

(2) To create in Peru, Bolivia and Chile laboratory facilities for analysing, evaluating and developing studies of copper mineral leaching.

The programme of technology development included seminar courses, on-site training by foreign experts and visits to dump leaching industrial operations in the United States. The project involved the joint participation of CENTROMIN PE RU, MINEROPERU and INCITEMI (now INGEMMET) in Peru, and COMIBOL and the IIMM in Bolivia. 1/ It was planned and coordinated by the Junta del Acuerdo de Cartage na (the Andean Pact).

The objectives of the Copper Project have largely been achieved in Peru, although to a lesser extent in Bolivia. Furthermore, there has been an impressive diffusion of the technology to other mine sites and firms, and an adaptation of it by the trained teams to other metallurgical problems. On the basis of this success the Andean Pact is planning a Second Phase which aims to consolidate and diffuse further bacterial leaching with the Andean Group and extend the technology development project to other metals and hydrometallurgical techniques. This has obtained financial assistance from GTZ of Germany, which was also the principal aid supplier for the Copper Project.

The main achievements of the Copper Project are outlined below:

(1) In the case of CENTROMIN, a large bacterial leaching pilot plant was installed at Toromocho using cementation on scrap iron as the recovery method. The team, based at the specifically created Special Projects Division in La Oroya, provided an important input to the prefeasibility study for the Toromocho industrial project, and a new pilot plant using

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1/ CENTROMIN, MINEROPERU and COMIBOL are the state-owned mining companies of Peru and Bolivia. IIMM is the Bolivian Institute for Mineral and Metal lurgical research. And INGEMMET is the Peruvian Institute for Geological, Mining and Metallurgical research.

a solvent extraction-electrowinning recuperation method is planned in order to obtain parameters for scale-up. A natural bacterial leaching process at Cerro de Pasco is being optimised, and copper from effluent solutions from both the mines and dumps is being recovered electrolytically.[1/]

(2) INGEMMET has now built up a strong capability in the area of bacterial leaching through applied R&D work on ore from MINEROPERU's mine at Cerro Verde. Since the oxide zone at that site is now nearly depleted it is planned to bacterially leach the remaining sulphide values from the previously sulphuric acid leached oxide piles and marginal ore from the underlying sulphide zone. The installed capacity of their solvent extraction plant may be adapted to recover the copper from the solutions. MINEROPERU, lacking the complete capacity itself due to the resignation of trained personnel, is planning to contract experts from INGEMMET to work with its own personnel at the mine site to develop and apply bacterial leaching.

(3) A R&D division was established within COMIBOL as a consequence of the Copper Project. Applied research was carried out there by the trained team on the bacterial leaching of copper ore from Tasna, and a pilot plant programme was subsequently planned though not implemented. In addition, some more innovatory research was carried out on marmatite (zinc) concentrates from Colquiri.

(4) Finally, the private sector in both Bolivia and Peru has shown much interest in bacterial leaching. In fact, a former team member from the CENTROMIN group, who was later contracted by HORSCHILD, is now directing the development of two bacterial leaching projects for that

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1/ By extracting the copper in this way, the associated ferric ions in solution are reconverted to ferrous ions and the previously acidic effluent is no longer highly pollutant in the River Mantaro. Similarly, one of the major reasons for Exxon's bacterial leaching project at Los Bronces was to avoid polluting the main river supplying Santiago's water by the natural leaching of the overburden from the mine.

firm. One is to be applied to marginal copper sulphide ore and the other to silver concentrates. 1/

When discussing "alternatives" to mineral technology development in developing countries a major issue of concern is the accumulation of local resources and skills in order to increase local participation in the development processes of their minerals sectors.

In relation to this the analyses of both the potential of bacterial leaching technology and the application of it within the Andean Region illuminate the following four general points:

(1) Processes of technical change and innovation in the minerals sector, when viewed at the project level, are highly complex. They are neither simply R & D initiated nor without their own political and social context. Bacterial leaching projects essentially require multidisciplinary teams working closely with the production sector (ie. not in city institutes distant from the mine sites of intended application). These projects require initial inputs from geologists, cooperation during implemetation from mining engineers, and R & D is an ongoing activity throughout the planning and operation of the process.

The Copper Project also illustrated the determining influence of the attitude of decision makers with power to the possibility of the application of both a new and unconventional technology independent from the multinational mining companies that are usually contracted to implement technical change. Each case of intended application of bacterial leaching in the Andean Subregion had a crucial example of one person's enthusiastic commitment to the technology.

1/ A microbiologist from a Lima University, who also worked at the Toromocho project, is included in the team.

(2) The analysis of the Copper Project indicates the fundamental input that technical knowledge makes to technology policy formulation and project planning and coordination. The project's architect was a metallurgist who had direct production experience and also expertise in technology policy formulation. Although based in the Andean Pact he was able to make links directly with the firms, encourage the teams, resolve problems and coordinate the technology transfer process checking as much information as possible was supplied.

Following on from this emerges the necessity to accumulate and consolidate both the technical and policy capability within organisations, rather than persons, so that people leaving are agents of technology diffusion rather than reasons for stopping a project. One of the reasons why the project did not reach the production stage in Bolivia was because the knowledge and experience gained from the training programmes and visits of the foreign experts was not consolidated. There were no internal training programmes and very few jointly written reports. There were several resignations and each new person entering the team had to begin researching almost from scratch. This meant several excellent ideas were developed but they went no further than the research stage. CENTROMIN, on the other hand, concentrated on the Toromocho project, which was also the site of practical training during the project. Information was shared, many joint reports were written and a manual of detailed procedures for carrying out bacterial leaching was compiled collectively. This largely explains the impressive progress in bacterial leaching demonstrated by this firm, despite changes of personnel, and the diffusion of the technology to Cerro de Pasco (CENTROMIN) and Pativilca (Horschild) by the trainees who resigned.

(3) Throughout its duration the project illustrated both the benefits and limitations of the international transfer of technology related inputs both from developed countries and between developing countries for

processes of endogenous technical change within the minerals industry. 1/

While foreign experts can effect a real transfer of technology through training programmes and accompanied site visits, their own economic constraints (eg. the necessity to obtain more contracts) and, their different conception of technology generation (based on their developed country experiences), can adversely effect technology transfer unless the project is well and continously coordinated. For example, a four phase training programme was presented by the technology supplier. This included: an introduction to bacterial leaching R & D; an evaluation of the leaching potential of various mines; the design of leach dumps and operation procedures; and, the continuous evaluation of the leaching process. He wrote that this would take about two years to complete. 2/

However, eight years later the expert was still recommending a continuance of the role of his institute as a consultant.and the monthly sending of progress reports and data to him for analysis. It emerges that an essential capability is to know to what extent and in what areas information can be obtained from foreign experts and at what stage the cooperation should be terminated.

Furthermore, the technology suppliers were accustomed to carrying out specific pieces of research under contract and suppling this directly to firms for commercial application. This may explain their preocupation with the R & D part of the process and their emphasis on the role of the research institutues. Apart from being inappropriate for the requirements of a bacterial leaching project (see above) the special conditions of developing countries, where R & D is often alienated from production and the demand for technology is directed towards the industralised countries,

1/ That is technical change designed controlled and implemented within the countries concerned -which is not to apply that foreign technology or experts can not play an important role.

2/ Grupo de Política Tecnológica de la Junta del Acuerdo de Cartagena. "Recomendaciones para el Desarrollo de un Programa de Lixiviación de Minerales Marginales de Cobre en Perú, Chile y Bolivia". J/AG/15, 12 Sept. 1972.

indicate the limitations of this approach. Detailed project planning, which included the participation of the firms, and the decision to carry out R & D within them, probably accounted for many of the projects achievements.

Although the COMIBOL case, and to a much lesser extent the CENTROMIN one demonstrate the necessity to include those concerned with actual production activities to ensure the optimal application of the technology.

With respect to technology transfer between mineral producing developing countries the Copper Project indicated that while there are obviously a vast number of technical problems of mutual interest their resolution through cooperative endeavours is subject to many constraints. Variation in composition and amount of reserves, differing costs of production and levels of technical advance as well as differences between each country's state of political and economic development, mean that cooperation has to be carefully planned.

The Copper Project clearly illustrated the advantages of joint seminar courses and visits to sites of industrial applications. However it also showed that effective technology transfer processes between developing countries are often more gradual than originally evisaged, especially where no prescedent exists. This means that the dynamic for their consolidation and continuation needs to be built into related policy so that the process can continue after projects oficially end.

(4) Finally, and most important of all in relation to "alternative" technology development for the minerals industry, is the tendency inherent within the development of bacterial leaching technology which leads to the localisation of the technical change process. This is because of the intrinsic necessity for local capability accumulation and utilisation. This in turn enhances control over technical change and, if consolidated, provides a dynamic for both technology diffusion processes and the application of the

capacity to other areas of technology development. The ongoing requirements involved in optimisating bacterial leaching operations similarily stimulate the accumulation of indigenous capabilities to effect incremental technical change which again leads to increased local participation.

In the Andean Pact Copper Project this was manifested in the clear trend for firms and institutes to reorganise themselves in order to efficiently develop and implement bacterial leaching projects. This involved the translation of the technical change activities, in some cases in spite of the policy,not just to the industrial sector but also closer to the production division within the firm.

There are two principal reasons for this:

Firstly,the essential input which site-specific mining, mineralogical and metallurgical knowledge forms during the design and implementation of bacterial leaching projects.

Secondly, the sheer inappropriateness and impracticality of trying to develop parameters to optimise the environment sensitive activity of the leaching bacteria outside of the production sector and away from the intended site of application.

In conclusion, as an alternative, or more exactly as an additional process route, the development and application of bacterial leaching technology in developing countries would pose a challenge in two main areas:

(1) Maximising the benefits of international technology transfer both from developed countries and between developing countries.

(2) Technology assimilation, adaption and generation.

Overall, given the context in which new mineral projects will be developed, although accepting bacterial leaching will not be appropriate in every case, it would appear that rising to meet this challenge would help maximise both the economic and social benefits from the development of the natural resources of the Southern Hemisphere. 1/

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1/ This paper is based on detailed fieldwork results and analyses presented in the forthcoming SPRU/UNIDO Report to be entitled: "The Application of Biotechnology in Developing Countries: The Case of Mineral Leaching with Particular Reference to the Andean Pact Copper Project."

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Export-Led Industrialization in the Third World: Manufacturing Imperialism

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ABSTRACT: The failure of import-substitution industrialization has led many bourgeois economists to prescribe for Third-World nations a strategy of industrialization based upon the export of manufactures to the developed capitalist world. South Korea, Taiwan, Singapore and Hong Kong, for example, are following this strategy and, according to these economists, are beginning to achieve indigenous capitalist development. Other Third-World nations are now starting to look upon these nations as models for Third-World industrialization.

In this new strategy of export-led industrialization, transnational corporations play a major role. By promoting only certain Third-World exports of manufactures, transnational corporations are using this strategy to help expand and control a new international division of labor. This development leads not, as bourgeois economists claim, to self-expanding Third-World industrialization, but to dependent industrialization as part of a new form of imperialist domination.

* * * * *

With 1979 marking the end of the Second United Nations Development Decade, the problems of poverty and underdevelopment in the Third World remain at least as great as they were at the beginning of the First United Nations Development Decade. Many Third-World governments, increasingly worried that capitalism's failure to induce Third-World development will eventually undermine their power, are desperately searching for an economic strategy that will lead to self-expanding capitalist industrialization. According to many bourgeois economists, the solution is industrialization based on the export of manufactures.

These economists point to countries like South Korea, Taiwan, Singapore and Hong Kong, all of which follow this strategy, as examples of Third World nations on the road to capitalist industrialization and development. The undeniable growth in production and export of manufactures by these countries, in conjunction with support from international economic institutions and developed capitalist country governments, has led to a growing number of Third-World nations adopting a similar development program. Export-led industrialization is now the dominant Third-World strategy for achieving capitalist development.

My investigation begins with an analysis of the failure of import-substitution industrialization as a model for Third-World development, and the historical conditions and pressures created by imperialism which led a number of Third-World nations to adopt a new strategy: industrialization based on the production and export of manufactures. Next, I identify the Third-World countries which lead in the export of manufactures and the types of goods they export, showing how transnational corporations have played a major role in shaping export-led industrialization and control most Third-World exports in the process of transnational corporate profit maximization. By studying the impact of export-led industrialization on the political economy of Third-World nations, I conclude that this strategy will lead not to the creation of indigenous, self-expanding capitalist development in the Third World, but to dependent industrialization as part of new form of imperialist domination.

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The Failure of Import-Substitution Industrialization

At the close of World War II, foreign domination of the Third World had not been broken.[1] Domestic planning and development were squeezed and limited by two interconnected pressures. First, with little industrial base countries were forced to spend large sums of foreign exchange to import almost all manufactured goods. Second, necessary foreign exchange could be earned only through primary commodity exports to the developed capitalist countries (DCCs), but these exports were continually subject to violent swings in demand and reduced purchasing power. The lack of foreign exchange sufficient to maintain even minimal levels of growth and consumption necessitated substantial foreign debt with continued foreign domination the result.

Fearful of growing internal pressures for change, and desiring to insure and expand their power, the national bourgeoise in a number of Third-World countries sought to break out of this position of dependence. Generalizing, their goal was to initiate self-expanding capitalist development, and their strategy was to pursue import-substitution industrialization (ISI). This choice of ISI as a development strategy flowed out of the constraints described above. Since primary commodity trade had proven unreliable, it was to have reduced emphasis. Since dependence appeared to rest on a continual lack of foreign exchange and the need to import all manufactured goods, ISI would pursue the replacement of these imports by boosting domestic production.

The logic of imperialism, however, kept this from succeeding. In choosing which goods to produce, the market, as always, responded to the existing class structure. The mass of the population remained poor, tied to the land for survival, and unable to provide a market for goods. Thus the decision to produce domestic manufactured goods could not mean the production of mass consumption goods.

Only the bourgeoisie was capable of supporting a domestic market and thus industrialization had to focus on luxuries and consumer durables and be concentrated in existing urban areas (further aggravating regional imbalances). The fact that tariffs would reduce finished imports from advanced capitalist countries, however, did not mean that the local bourgeoisie had the capital or technology to begin their own domestic industrialization. The result was foreign debt and participation by foreign (primarily U.S.) transnational corporations. Although projects were often joint ventures with contribution by local capital, "independent" development was soon transformed into dependent industrialization under the leadership of foreign capital. Moreover, while local production did at first lead to a reduction in imports, after a brief period the foreign exchange saved was far surpassed by the foreign exchange spent for the importation of basic inputs and capital goods, and by the massive outflow of profits back to the transnational corporations' home countries, primarily the U.S. Thus, although the composition of Third-World countries' imports did change, their balance of payments deficits continued to grow.

For Third World countries, the results of ISI were anything but positive: (1) greater starvation for the majority of the people, (2) limited industrialization, (3) growing regional inequalities, and (4) larger deficits and debt.

The New Strategy: Export-Led Industrialization

By the 1960s, the bourgeoisie in most Third-World nations were forced to admit that ISI had been a failure. Their goals of diversified and self-generating industrialization and economic independence had both been frustrated. With internal class pressures building and national liberation struggles successfully organizing people around an anticapitalist ideology, the national bourgeoisie realized a change in strategy was necessary. And so in the early 1960s, a new approach to development (once again flowing out of the logic of imperialism) was advanced.

Given the precarious debt position facing most Third-World nations, it was not surprising that the linchpin of this new strategy was increased exports.

TABLE I:

TRENDS AND CHARACTERISTICS OF WORLD TRADE IN MANUFACTURES[a]

World trade in manufactures	*World[b] Total*	*Developed Countries*	*Developing Countries*
(1) Percentage share in world exports			
1960	100.0	83.9	3.8
1969	100.0	84.6	5.1
(2) Cumulative annual growth rates 1960-1969			
Manufactures	10.8	10.9	14.3
Primary commodities	5.7	5.9	5.8
(3) Percentage share of exports of manufactures in total exports of goods			
1960	51.3	64.4	9.2
1969	60.5	72.3	16.8

NOTES: [a]SITC sections 5, 6, 7 and 8, excluding division 68
[b]Includes socialist world.

SOURCE: *Economic Bulletin for Latin America* 17 1 (1972) p.42.

Unless foreign exchange pressures could be alleviated, no real planning was possible. In a sense this strategy completed a full circle: once again Third-World development was to be tied to the external market. However, with industrialization still a major goal, there was to be a change in the composition of exports. In the past, export-led development concentrated upon primary commodity sales to the developed capitalist countries. Now, it was to be based upon the production and export of manufactures. By this strategy, the bourgeoisie hoped to industrialize, reduce domestic tensions through increased employment, earn foreign exchange, and stimulate the process of domestic capitalist development.

The Third-World's shift to production of manufactures for export is documented in Table 1. Between 1960 and 1969, total world exports grew at an average annual rate of 8.8% Breaking down that total reveals a 10.8% increase for manufactured goods compared to a 5.7% increase for primary commodities. This trend toward greater trade in manufactures (by 1969 they accounted for 60.5% of total exports) was, as shown in Table 1, most pronounced among Third-World nations.

Third-World countries continued to trade mostly in primary commodities. But, as a result of this new development strategy, manufactured exports (narrowly defined) as a percentage of total Third-World exports increased from 9.2% in 1960 to almost 17% in 1969. Manufactured goods narrowly defined refers to chemicals, basic manufactures, machinery and transport equipment, and miscellaneous light manufactures. Manufactured goods broadly defined includes additional items such as a number of processed products, e.g., processed foods and wood and paper products.[4] Using the broader definition of manufactures, the share of manufactures in total Third-World exports increased from 21% in 1967 to 27% in 1971 to 40% in 1976.[3] In fact, between 1970 and 1976, Third-World exports of manufactured goods (broadly defined) to DCCs increased in volume terms at an annual rate of 14% — or more than twice as fast as imports of manufactures into DCCs from the world, twice as fast as manufacturing output growth in the Third World, and four times as fast as manufacturing output growth in the DCCs (see Figure I).[4]

Third World production and export of manufactures is characteristic of a new international division of labor. The classical international division of labor was based upon a small core of heavily industrialized developed capitalist countries trading with a larger number of raw-material supplying Third-World nations. The production and export of manufactures has now spread to new locations in the Third World.

Countries and Products:
Who's Exporting What to Whom?

In order to evaluate MEI as a development strategy, it is necessary to examine specific Third-World nations and their export performance. This task is facilitated by the fact that relatively few Third-World countries produce the great majority of manufactured exports.

In 1973, for example, Hong Kong, South Korea, Singapore, Malaysia, Mexico, Argentina, Brazil and India accounted for approximately 75 percent of all Third World manufactured exports (broadly defined) to DCCs (see Table 2).[5] More specifically, Table 3 shows that our eight countries accounted for an overwhelming percentage of all Third-World exports to DCCs in three product lines: engineering and metal products, clothing, and miscellaneous light manufacturing. They were also well represented in leather and footwear, wood products and furniture, and textiles. Using the most restrictive definition of manufactures, and 1972 data, these eight countries accounted for almost 60% of *total* Third World exports of manufactures and over 65% of *total* Third-World industrial production.

There are, however, some important differences among these eight leading exporters. Mexico, Brazil, Argentina and India (Group A) accounted for over 55% of all Third-World industrial production but only about 25% of all Third-World manufactured exports (narrowly defined). Hong Kong, Malaysia, Singapore.

TABLE 2:

THE TOP EIGHT THIRD WORLD[a] EXPORTERS OF MANUFACTURES[b] TO 21 DEVELOPED CAPITALIST COUNTRIES IN 1973 (Millions of U.S. dollars)

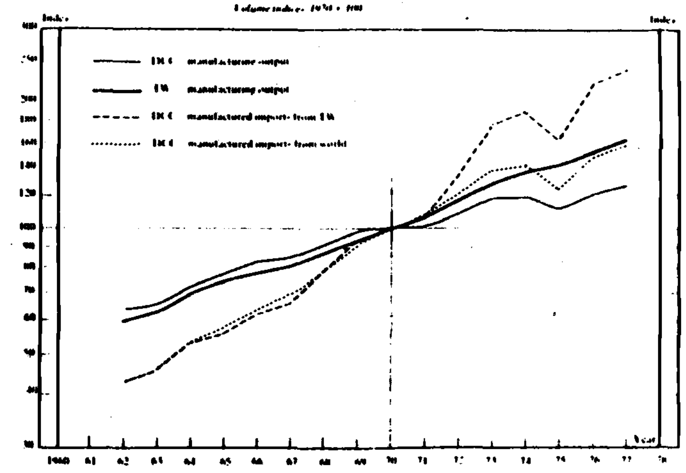
Country	*Value*	*% of total third world exports to 21 developed capitalist countries*
Hong Kong	3260	23.0%
Republic of Korea	2234	15.7%
Mexico	1260	8.9%
Brazil	1139	8.0%
India	872	6.1%
Singapore	840	5.9%
Malaysia	560	3.9%
Argentina	443	3.1%
	10608	74.7%

NOTES: [a]Yugoslavia and Israel are not considered Third-World countries. Taiwan is not included in U.N. computations.
[b]Excluding petroleum products and unwrought nonferrous metals.

SOURCE: UNCTAD Secretariat, *Trade in Manufactures of Developing Countries and Territories, 1974 Review* (New York, 1976), p.26.

FIGURE I.

[illegible]



NOTES: [illegible]

SOURCE: UNCTAD Secretariat, [illegible]

TABLE 3:

EXPORTS OF MANUFACTURES[a] TO 21 DEVELOPED CAPITALIST COUNTRIES — 1973 (millions of U.S. dollars)

	Hong Kong	*Republic of Korea*	*Mexico*	*Brazil*	*India*	*Singapore*	*Malaysia*	*Argentina*	*21 DCC[b]*	*% by 8[c]*
Clothing	1393	644	106	44	80	116	20	18	2650	91.4
Other Engineering and metal products	649	337	559	115	48	472	81	35	2453	93.6
Textiles	336	308	100	143	432	32	16	10	2275	60.5
Wood Products and Furniture	35	330	52	163	8	141	385	1	1587	70.3
Miscellaneous Light Manufactures	719	230	93	22	25	38	5	16	1292	88.9
Food Products	23	67	73	308	17	19	36	159	1217	57.7
Leather and Footwear	59	109	26	140	195	3	4	102	823	77.5
Chemicals	15	35	89	75	24	17	6	47	614	50.2
Iron & Steel	3	115	26	69	31	1	—	43	552	52.2
Drink & Tobacco Products	—	1	73	5	—	—	—	3	220	37.3
Others	28	58	63	55	12	2	6	9	506	46.0
TOTAL ABOVE	3260	2234	1260	1139	872	842	560	443	14189	74.8

NOTES: [a]Excluding petroleum products and unworked non-ferrous metals.
[b]Total imports by Developed Capitalist Countries from the Third World by product line. Yugoslavia and Israel are not considered Third World countries. Taiwan is not included in U.N. computations.
[c]The percentage of total imports by Developed Capitalist Countries from the Third World accounted for by the eight Third World Countries listed.

SOURCE: UNCTAD Secretariat, *Trade in Manufactures of Developing Countries and Territories, 1974 Review* (New York, 1976), p.48, 49, 50.

TABLE 4:

PER CAPITA EXPORTS OF MANUFACTURES[a] BY SELECTED THIRD-WORLD COUNTRIES TO THE DEVELOPED CAPITALIST COUNTRIES — 1973

Country	*Population Mid-1973 (millions)*	*Manufactured[a] Exports Per Capita in Dollars*
Hong Kong	4.2	784
Singapore	2.2	384
Korea	32.9	68
Malaysia	11.3	49
Mexico	54.3	23
Argentina	24.3	18
Brazil	101.4	11
India	574.2	1.5

NOTES: [a]Excluding petroleum products and unworked nonferrous metals.
SOURCE: UNCTAD Secretariat, *Trade in Manufactures of Developing Countries and Territories*, 1974 Review (New York: 1976), p.28.

and South Korea (Group B) were responsible for less than 10% of Third-World production *but* 35% of all Third World manufactured exports (narrowly defined).[6]

It is not surprising that Mexico, Brazil, Argentina and India are leading Third-World exporters of manufactures because each has a relatively large domestic industrial base and established infrastructure. Hong Kong, Malaysia, Singapore and South Korea represent almost a completely opposite situation. They have few natural resources, small domestic markets, and little infrastructure. Yet, as the data presented above shows, by rooting their industrial base in the needs and logic of the international capitalist economy, they have become very successful exporters (see Table 4) — especially to DCCs.[7]

The differences between Groups A and B are significant to our understanding of export-led industrialization. In order to more fully appreciate these differences, we will look at the structure of each of the eight nations' manufactured exports to the developed capitalist world. The focus will be on exports to DCCs because these make up the great majority of Third-World exports.

We now examine the data in Table 3 by country, starting with those in Group A. Argentina's exports are primarily food products and leather and footwear. India is the leading exporter of textiles and leather and footwear. Brazil is the leading exporter of food products and has significant sales in wood products and furniture, textiles, and leather and footwear. It is important to note that all three of these countries are primarily exporters of traditional manufactured goods, and that many of these processed raw material exports occur because of natural-resource conditions in the country.

· Mexico stands as an exception to the other countries in Group A. It is a major exporter of engineering and metal products and has significant sales in clothing, textiles and light manufacturing. These export categories, except textiles, represent components of a less traditional, more modern industrial base. Mexico's success in these areas, however, is tied to its Border Industrialization Program. Production in the border area accounts for over 25% of total exports and almost all the exports of nontraditional manufactures.[8] If the border area were considered part of Group B, Mexico would no longer be considered an exception.

If we look at countries in Group B we see a contrasting situation. Hong Kong, for example, is the leading exporter in clothing, light manufactures, and engineering and metal products. South Korea exports a significant amount of clothing, and engineering and metal products. Singapore specializes in engineering and metal products. Malaysia, the exception in Group B, concentrates on export of traditional manufactures — wood products and furniture. It is, however, currently increasing its exports of engineering products.

With reference to those product categories in which the eight countries account for a majority of Third-World exports to DCCs, it appears that Group A (with the Mexican border area as an exception) specializes in traditional resource-based exports, while Group B specializes in more modern industrial product exports. This difference in emphasis is part of an important trend. In the early 1960s, about 67% of all manufactured goods which Third-World countries exported to DCCs were products made from foodstuffs, tobacco, wood, textiles and leather. The nontraditional manufactured exports (clothing, engineering goods, and light manufacturing) accounted for only 18%. By 1973 the situation was reversed with traditional exports accounting for only 40% of total export value and the nontraditional products 45%.[9]

This point is made even sharper if we concentrate on exports to the United States (see Table 5). Group B countries — Hong Kong, South Korea, and Singapore — emphasize exports in clothing, engineering and metal products, and light manufactures. Group A countries — Argentina, India and Brazil — emphasize more traditional exports in product lines like leather and footwear, food products and textiles. Looking at the overall composition of imports into the U.S. from the Third World (Table 6), we see that almost 60% of the total imports are clothing, engineering and metal products, and light manufactures.

We can now generalize the differences between Group A and Group B. The countries in Group A are large, have significant natural resources and appear to have a base for successfully exporting a broad range of manufactures. Yet, their exports to the DCCs are concentrated on those goods that are connected to their

TABLE 5:

EXPORTS OF MANUFACTURES[a] TO THE UNITED STATES — 1973
(millions of U.S. dollars)

	Hong Kong	*Republic of Korea*	*Mexico*	*Brazil*	*India*	*Singapore*	*Malaysia*	*Argentina*	*U.S.[b]*	*% by 8[c]*
Clothing	435	246	100	22	16	83	—	—	1111	81.2
Other Engineering and Metal Products	379	199	540	64	—	287	—	—	1650	89.0
Textiles	91	20	59	27	189	—	—	—	565	68.3
Wood Products and Furniture	—	174	49	43	—	10	31	—	489	62.8
Miscellaneous Light Manufactures	373	142	84	12	7	10	—	—	714	88.0
Food Products	8	15	59	112	—	—	3	79	415	66.5
Leather and Footwear	8	63	—	93	15	—	—	49	280	81.4
Chemicals	—	2	43	28	7	—	—	11	188	48.4
Iron & Steel	—	72	24	33	11	—	—	33	266	65.0
Drink & Tobacco Products	NA	NA	NA	NA	NA	NA	NA	NA	29	
Others	NA	NA	NA	NA	NA	NA	NA	NA	228	

NOTES: [a]Excluding petroleum products and unworked nonferrous metals.
[b]Total imports by the United States from the Third World by product line. Yugoslavia and Israel are not considered Third World countries. Taiwan is not included in U.N. computations.
[c]The percentage of total imports by the U.S. from the Third World accounted for by the Eight Third-World countries listed.
SOURCE: UNCTAD Secretariat, *Trade in Manufactures of Developing Countries and Territories*, 1974 Review, (New York: 1976), pp.15, 16, 17, 18, 19, 20, 22.

natural resource endowment, and that represent a declining percentage of total imports into the U.S. and other DCCs. Group B countries have small internal markets and relatively undeveloped industrial infrastructures. Yet they specialize in nontraditional manufactures and successfully compete against larger and more developed Third World countries in DCC markets.

Export-Led Industrialization: What's Behind its Growth?

Central to the growth of Third-World exports of manufactures to DCCs is "International Sub-contracting."[10] The term refers to a relationship whereby, in order to cover markets in an advanced capitalist country, transnational corporations arrange to use Third-World firms to produce entire products, components, or services. The arrangement can be initiated by a producer firm, i.e., a firm that produces similar products, or by a retailing firm, i.e., a firm primarily involved in product distribution. Regardless, the transnational corporation will always control final marketing of the product and, more often than not, provide technical assistance, management, loan capital and physical equipment for the subcontractor. While there are a variety of possible legal relationships between the transnational corporation and subcontractor, ranging from wholly-owned subsidiary to independent producer, the key point is that Third-World exports to DCCs are part of a complete organizational structure

TABLE 6:

IMPORTS OF MANUFACTURES[a] FROM THE THIRD WORLD BY THE UNITED STATES, 1973

Product Group	*Value of Imports (in U.S. millions)*	*Composition of Imports in %*
Clothing	1111	18.7%
Other Engineering and metal products	1650	27.8%
Textiles	565	9.5%
Wood products and furniture	489	8.2%
Miscellaneous light manufactures	714	12.0%
Food products	415	7.0%
Leather and footwear	280	4.7%
Chemicals	188	3.2%
Iron and steel	266	4.5%
Drink and tobacco products	29	.5%
Others	228	3.8%
TOTAL ABOVE	5935	100. %

NOTES: [a]Excluding petroleum products and unworked nonferrous metals.
[b]Yugoslavia and Israel are not considered Third World Countries. Taiwan is not included in U.N. computations.
SOURCE: UNCTAD Secretariat, *Trade in Manufactures of Developing Countries and Territories*, 1974 Review, (New York: 1976), p.39.

dominated by firms from advanced capitalist countries. For example, while Sears may contract with an independent firm in Hong Kong to produce standard white polyester shirts, Sears retains complete control over research, advertising, and marketing.

No one knows the exact size or rate of growth of Third-World international subcontracting. A rough

TABLE 7:

U.S. IMPORTS UNDER TARIFF ITEMS 806.30 AND 807.00
(in millions of dollars)

	1966	1967	1968	1969	1970	1971	1972	1973
Total imports into U.S. under Tariff Items 806.30 and 807.00	953.0	1,035.1	1,554.4	1,841.8	2,212.7	2,768.2	3,408.7	4,242.1
Total imports under Tariff Items 806.30 and 807.00 from the Third World	60.7	99	221.7	394.8	541.5	652.5	1,031.7	1,522.9
Third World imports into the U.S. as a percentage of total imports under Tariff Items 806.30 and 807.00	6.4%	9.6%	14.3%	21.4%	24.5%	23.6%	30.3%	35.9%

SOURCE: Michael Sharpston, "International Sub-contracting," *Oxford Economic Papers,* March 1975, pp.96-97.

TABLE 8:

MISCELLANEOUS COMPARISONS OF WAGES
(U.S. $/hour)

Industry	*Place*	*Date*	*Basic Wage*	*Wage with Benefits*
Garment making	Korea	1967	.10	—
	Morocco outside Casablanca	1972	.22-.27	.29-.36
	Hong Kong	1967	.24	—
	Portugal	1967	.25	—
	Morocco: Casablanca	1972	.24-.42	.36-.58
	Japan	1967	.35	—
	Italy	1966	.49	.90-1.00[a]
	France	1966	.57	
	Germany	1966	.85	1.18
	United States	1967	2.01	
Office machine parts, including electronic memories	Mexico	1969	—	.48
	Singapore, Korea, Hong Kong	1969	—	.28-.30
	Morocco	1972	.21-.27	.28-.36
Semiconductors[e]	Mexico	1969	—	.61
	Singapore, Korea, Hong Kong	1969	—	.28-.33
Consumer electronic products[e]	Mexico	1969	—	.53
	Hong Kong	1969	—	.27
	Taiwan	1969	—	.14
Manufacturing	Morocco outside Casablanca	1972	.30 (.22-.44)[b]	.40 (.30-.60)[b]
	Morocco: Casablanca	1972	.45 (.33-.58)[b]	.60 (.44-.80)[b]
	E.E.C.	1966	.75-1.15[c]	1.25-1.60[c]
	U.S.A.	Feb. 1972	—	3.71[d]

NOTES: [a]Figures for all individual E.E.C. countries, except Germany, are in this range.
[b]Unbracketed figure is most typical wage over all. Bracketed figures show range over which wage varied from plant to plant.
[c]Range over which wage varied between individual E.E.C. countries.
[d]Some charges excluded.
[e]Job classifications are not quite uniform. If the same jobs had been performed in the U.S., estimated earnings in U.S. $/hour (including supplementary compensation) would be: 1) *Office machine parts* (including electronic memories), Mexico—$2.97; Singapore—$3.36; Korea—$2.73; Hong Kong—$2.92. For Morocco, comparable U.S. earnings in 1969 are not available. 2) *Semiconductors,* Mexico—$2.56; Singapore—$3.22; Korea—$3.32; Hong Kong—$2.84. 3) *Consumer electronic products,* Mexico—$2.31; Hong Kong—$3.13; Taiwan—$2.56.

SOURCE: Michael Sharpston, "International Sub-contracting," *op. cit.,* p.105.

estimate of growth for the U.S. can be calculated by using figures for U.S. imports under Tariff items 806.30 and 807.00. These tariff items levy import duties on value added abroad if the inputs originated in the U.S. These figures are not identical with international subcontracting as defined above since they do not include products produced completely abroad. These figures also differ from the real figures for international subcontracting because technicalities in the tariff items exclude many imports produced as a result of subcontracting. For example, U.S. cloth cut in the U.S. and sewn abroad is included in the data, while U.S. cloth cut and sewn abroad is not.

In spite of the above limitations, Table 7 does give information on the rapid growth of international subcontracting with the Third World. We see that the share of imports allowed under these two items, accounted for by the Third World, increased from 6.4% in 1966 to 21.4% in 1969 to 35.9% in 1973. While Third-World imports under these two items remain small relative to total U.S. imports, the rate of growth is significant. From the viewpoint of many Third-World countries, that increase represents substantial economic activity.

There are perhaps three main reasons for the major growth of international subcontracting. The first, primarily "economic," is the growth of new labor-intensive manufacturing industries like electronics and light manufacturing, joining older labor intensive-industries like clothing and shoes. This has taken place because many advanced consumer products in the DCCs have become standardized and sold in mass markets. The development of international subcontracting in these product lines has also been advanced by new technological innovations in transportation and communication. With improved air freight, containerization, and telecommunication, transnational corporations could dispatch products and components quicker, cheaper, and safer.

The second reason for subcontracting is capitalist rivalry. Immediately after World War II, the U.S. was the dominant capitalist power. When Third-World nations embarked upon their import-substitution industrialization plan by shutting off their markets to imported finished products, only U.S. transnational corporations could undertake large-scale direct investment in Third World manufacturing. U.S. expansion during this period was directed at securing markets in the Third World, not at establishing export bases in order to supply home markets. (The majority of direct investment was in Latin American countries with sizable domestic markets — Mexico, Brazil and Argentina.)

In the mid-1960s, however, the international situation began to change as Germany and Japan competed heavily against the U.S. These two countries had developed as export-led economies and increasingly challenged U.S. business for markets because they had relatively cheap labor, more government assistance, and more modern plants and equipment. U.S. transnational capital met this challenge partly by means of international subcontracting. By employing Third-World labor, U.S. markets were protected. (U.S. action, as one would expect has forced Japan and Germany into a similar strategy.[11]

The third reason for business to engage in international subcontracting was growing internal class pressures and struggles. In the U.S., for instance, by the mid-1960s, capitalists were no longer able to maintain high profit margins and yield to working-class demands for material and political gains. Given international economic pressures (large balance of payments deficits) and domestic economic pressures (inflation, full-employment profit squeeze), U.S. capitalists could not successfully restore profit margins through continued price increases. One way of reducing costs and combatting full-employment pressures at home was to involve Third-World workers, through international subcontracting, more directly in production for the U.S. market. Thus the logic of global capitalism led to the expansion of a new international division of labor under the control and direction of transnational corporations.

It is essential to indicate the profitability of subcontracting because this is an obvious motivating concern of transnational corporations. Since subcontracted jobs tend to be labor intensive, we look at figures for productivity and wage differentials. Beginning with productivity, a Tariff Commission report in 1970 found that the greatest difference between labor productivity in the U.S. and other countries was in garment making in Mexico — just over 60% of the U.S. level.[12] For electronics assembly, foreign productivity was, on average, almost 90% of U.S. levels, and for many other products, it was found to be even higher than in the U.S.[13] Productivity tended to be high under subcontracting because management, design, and even technology might be identical to that used in the DCC. In addition, labor problems — unions, strikes, absenteeism — are kept down by the fear of starvation, repressive labor legislation or armed force.

While foreign productivity certainly compares favorably with U.S. levels, it is only one side of unit labor costs. Turning to wages we see more clearly the gains to capitalists from subcontracting. Table 8 gives some indication of the enormous wage differences enjoyed by transnational corporations. Differences are so big that, according to Sharpston, "Even if U.S. wages go up by 5% and Korean by 20% — the absolute differential between the rates becomes larger."[14] According to data from the U.S. Tariff Commission, the net Far East labor cost for electronic assembly works out to be only 8% of that in the U.S. International subcontracting for certain manufactures appears to be very, very profitable.

Given the growth of international subcontracting, Group B countries were the ideal candidates. Since labor is the key variable, the poorer countries — those with less industry to compete for workers — appear most desirable. Since the final market to be served is the developed capitalist market, the internal market size of the Third-World country is not a key factor. Economies of scale, and modern capital-intensive technology are all possible, even in a small, underdeveloped Third-World country, because production is geared for export. Another factor determining the countries in which corporations choose to subcontract is the countries' dependence on foreign trade. The more dependent on foreign trade, the more likely they are to offer business attractive terms, e.g., tax holidays, free trade zones, and repressive labor conditions, and the less likely they are to disrupt the international movement of goods for domestic purposes. Above all, however, is the concern transnational corporations have for the political safety of their investments. By subcontracting, corporations are relying upon Third-World production to assist in supplying the important home market; it is therefore not surprising that subcontracting has been concentrated in only a few politically safe countries. U.S. transnational corporations, for example, have over 85% of all subcontracting work done in five countries, most of whose governments are directly dependent upon the U.S. for survival — Mexico, Taiwan, Hong Kong, Singapore and South Korea.[15]

While advantages from subcontracting are obvious for transnational corporations, the bourgeoisie in countries like South Korea, Taiwan, Malaysia, Hong Kong and Singapore also saw possible gain. They were willing to give up control over design, research, advertising, and marketing in order to follow a strategy they hoped would lead to self-expanding capitalist industrialization and thus increased power and wealth for themselves. Since Group B countries are presently the most committed to the strategy of export-led industrialization, the remainder of this paper will focus on the impact of MEI relative to them. This simplification is made because Group A countries appear to occupy a very different place in the international capitalist system and require separate study.

Export-Led Industrialization: A False Promise

I have shown that MEI is an important phenomenon, that its growth can be understood as part of the development of a new international division of labor under the direction of transnational capital. In this section I show that, for the Third World, MEI represents only a new form of international capitalist domination, not a program for establishing indigenous capitalist development or for meeting the needs of Third-World workers and peasants.

Export-led industrialization strategy blocks the development of an internally articulated, self-expanding economy. An economy which responds to the needs of the majority of the population is characterized by *convergence* between needs, domestic demand, investment, and resource use. In other words, the needs of the people must create effective demand calling forth investment and development of appropriate technology, domestic resource use, and production. Domestic consumption both completes the production/consumption cycle and provides the basis for a new cycle by creating new needs and demands. By responding to the needs of workers and peasants, such an economy generates employment, technology, and growth as part of a self-expanding process.

The above sketch of an ideal-type — the self-expanding economy — contrasts sharply with the *dynamic divergence* of Third-World export-led industrialization. Due to inadequate income, workers and peasants are usually unable to translate their needs into effective demand. Market demand comes largely from the small middle and upper classes and is heavily oriented toward products not produced domestically. As a result, a rise in Third-World demand leads to an increase in imports rather than domestic production. And since the workers and peasants lack income, domestic production is largely for export. Thus investment, technology, and resource use develop in response to demand in DCCs and tend to be unrelated to the needs of workers and peasants in countries following this road to economic "growth."

The dynamic divergence economy has no internal linkage between production and consumption. Goods produced are not consumed domestically; goods consumed are not produced domestically. It is, of course, possible for both the consumption of the middle and upper classes (largely imports) and domestic production (largely exports) to increase at the same time. This usually occurs, however, without creating the basis for self-generating economic expansion and blocks fulfillment of the needs of most Third-World people. With both production and consumption tied to the developed capitalist economies, economic "development" of a Third-World nation following a strategy of export-led industrialization only reinforces its dependence on DCCs.[16]

Subcontracting operations normally specialize in the use of low-skilled labor. The jobs tend to be those which are not easily mechanized, such as sewing. Since 80% of the labor costs in clothing manufacturing are sewing costs, clothing manufacturing is often subcontracted. Another example is assembly work, such as in the production of semiconductors. Corporations bring

chips and other components together in Taiwan, hire workers to assemble them under magnification, and then export the assembled semiconductors back to the United States. While the overall production of semiconductors is both skilled and capital intensive, it is the assembly process that is labor intensive in DCCs and therefore suitable for the Third World. Since related operations are either capital intensive or require skilled labor, transnational corporations do not usually subcontract them. The logic of subcontracting, therefore, makes it very unlikely that a Third-World country will be able to establish forward or backward linkages to produce the entire product, or upgrade the skill level of its work force.

There are limits built into a development process based on subcontracting such tasks. In the DCCs, corporations tend to use technology to mechanize manufacturing operations as much as possible, and to reduce the importance of parts and processes that cannot be mechanized (e.g., fewer parts to be assembled). This tendency, which obviously can be influenced by the relative costs of mechanization in the DCCs and labor in the Third World, would seem to place limits on the expansion of employment and on the number of processes to be subcontracted.

Transnational corporations also subcontract production which is standardized, technologically simple, and requires little capital overhead. Examples of products are sporting goods, toys, wigs, and plastics. These goods can be produced anywhere and transnational corporations subcontract their production in order to minimize possible future competition from other corporations which might take advantage of cheap foreign labor.

All of the operations described above can be characterized by their use of unskilled labor and elementary production processes. In general, there appears to be no basis for assuming that such economic activity will result in the transfer of useful technology or the upgrading of skill levels in the Third World. Moreover, little of this production will generate internal linkages, support a domestic mass-consumer market, or meet vital social needs.

The increase in Third-World manufacturing production has resulted, however, in a significant growth in the size of the industrial working class. One United Nations publication describes this fact:

> ... in developed market-economy countries employment in manufacturing increased at an annual rate of 1.4 percent between 1955 and 1974, but in the most recent period, 1970-1974, the annual increase was merely 0.3 percent. In developing countries, employment in manufacturing increased by 4.3 percent per annum between 1955 and 1974 and by as much as 6.5 percent per annum between 1970 and 1974.[17]

A changing class structure in the Third World should have profound political significance. The substantial growth in the industrial work force may, for example, provide a new and significant base for anti-imperialist, anticapitalist activities. Export-led industrialization may reinforce existing Third-World dependence, but it also produces important changes in the political economy of the Third World.

Subcontracting production can take place under a number of different relationships: transnational foreign affiliate production, joint venture, or independent Third-World production. Transnational foreign-affiliate production accounts for most Third-World production of semi-conductors, electronic memory circuits, engineering products and capital intensive goods. Most manufactured exports, however, are not produced under this legal structure. Estimates of the percentage of Third-World manufacturing exports which were produced by majority-owned foreign affiliates in 1972 are: Hong Kong, 10%; Taiwan, 20%; South Korea, 15%, and Singapore, 70% (Singapore's percentage is high because of a concentration in engineering exports).[18]

Independent Third-World firms and firms from DCCs working in joint venture with Third-World firms produce finished consumer electrical products, small machines, machine tools, cameras, clothing, sporting goods, toys and wigs. Superficially, this situation looks like diversified independent production and industrialization.[19] In the great majority of cases, however, transnational corporations retain complete control over the entire process (research, design, transport, processing, storage, and marketing). Even when an independent Third-World firm controls production, advertising, technology and management are almost always under the complete control of either a purely retailing corporation (such as J.C. Penney, Sears and Roebuck, Macy's, Bloomingdale's) or a trading or distributing company established by a producing transnational corporation.[20]

The result is that independent Third-World firms can be prevented, by transnational corporations, from producing for the local market or direct exporting. Third-World firms are dependent upon DCC firms for inputs and access to markets and since Third-World firms undertake little research or development on their own, they lack skilled personnel and experience in home production and direct exporting. Local firms use technology chosen by transnational corporations and depend upon them for service and technical assistance. Subcontracting under these conditions only advances a process of dependent industrialization, not self-generating capitalist reproduction. It does highlight, however, the importance to transnational corporations of technology and marketing as weapons of dominance.

It is true that at present some upgrading and expansion is taking place in certain Third-World countries. In Hong Kong and Singapore some foreign affiliates now completely produce transistors and integrated circuits locally. In South Korea networks of small manufacturers subcontract some work domestically and a South Korean program to encourage export diversification includes shipbuilding and steel production. Singapore no longer gives as many advantages to firms considering setting up plants for very low-skilled subcontracting. For example, "Hewlett Packard was denied tax incentives in connection with packaging integrated circuits, but did secure tax concessions for the production of electronic calculators."[21]

In some cases such development is nothing but an enlargement of an already existing manufacturing enclave.[22] In other cases, as in South Korea, it may represent attempts by the domestic bourgeoisie to gain a measure of independence from transnational corporations. Within the context of a strong commitment to export-led industrialization, it is not surprising that the bourgeoisie in Group B countries are trying to upgrade and diversify their exports in order to build a more dynamic economic base and increase their own independence and power. There are, however, a number of checks on their ability to succeed. One of the most important is the creation, with the support of transnational corporations, of new rival export centers.

Countries in Asia (Indonesia, Philippines, Thailand), the Caribbean and Central America (Haiti, El Salvador)[23] and the West Indies (Netherlands Antilles) are now competing for new and existing subcontracting work. Competition between Third-World countries for export business takes place in a number of different ways, and all of them increase the profits and power of transnational corporations at the expense of Third-World workers and peasants. Some countries compete in terms of financial policies. They offer generous tax holidays although there is no proof that these have any effect, other than to reduce government revenues. Many countries are forced to offer corporations subsidized credit even though it is illogical for a capital-scarce nation to offer funds to capital-rich transnational corporations.[24]

Many countries compete for subcontracts by offering bonus exchange rates and other export subsidies; if the bonuses become too large, however, the Third-World country can lose foreign exchange by exporting. This can happen, since under subcontracting most components or capital inputs must be imported and thus paid for with foreign exchange. When a final product is exported, only part of what is earned can be considered as net foreign exchange. So, if the imports are expensive and the price of exports artificially lowered, the entire transaction can result in a loss for the Third-World nation.

Third-World governments also try to encourage subcontracting in their countries by allocating foreign exchange and duty-free importation of supplies and equipment to corporations if they produce goods for export. Both foreign-exchange and tariff advantages, however, work to ensure that production will be biased toward producing goods for DCC markets, local supplies or suppliers will not be used, and internal linkages will not take place.

Finally, competition is also carried out through the establishment of free trade zones.[25] These are industrial parks, constructed and paid for by Third-World nations who turn over their governance and administration to foreign capital engaged in exporting. Countries anxious to encourage exports are literally willing to give up sovereignty to foreign capital in order to foster industrialization.[26]

The competition for subcontracting has already begun to hurt Group B countries. For example, in Hong Kong and Singapore, labor costs are rising; in the former, industrial land is becoming scarce. As a result, transnational corporations are slowing employment and production of semiconductors and memory arrays in those countries, and new production (sometimes even transfer of existing work) is being shifted to Malaysia, El Salvador, Thailand, and Indonesia.[27] Jobs and production are lost and export diversification and capital accumulation is retarded. The development of new export centers and the resulting competition increases the flexibility and profits of transnational corporations. In the Third World it limits wage increases, thus maintaining poverty and underdevelopment, and reinforces reliance on the external market, thus strengthening internal disarticulation and dependence.

Export-Led Industrialization and the Crisis of Capitalism

Some countries have increased output and employment through subcontracting. Continued gains, however, depend upon the stability and growth of markets in DCCs and such dependence is fraught with danger. That danger is the instability of the global capitalist economy on which the MEI development strategy depends. Figure 1 illustrates this by showing the sharp drop in Third-World-manufactured exports resulting from the downturn experienced by the capitalist system in 1974-75.

The cyclical downturn of 1974-75 hurt Third-World manufacturing output and export.[28] The growth rate of manufacturing output in the Third World fell from 9.5% in 1973 to 6.5% in 1974 to 3% in 1975. The 1975 reduction was especially severe in Hong Kong, South Korea and Singapore, since these countries rely heavily on exports to the DCCs. The overall volume of world trade in manufactures decreased by 5% between 1974-75, but Third-World exports to DCCs decreased by even more, producing an overall decrease in the Third-World's share of imports into the DCCs. In 1975 the Third-World's share fell in 11 of the 21 DCCs. Even during the downturn, however, the Third World did not stop exporting manufactures. Thus, in 1975, the market share of Third-World-manufactured exports was higher for every DCC than it had been in 1970; in nine countries it was higher than it had been in 1974.

The internation capitalist world is currently facing serious economic problems and they are not ones of short-term business cycle management, but of cyclical instability in the context of global stagnation. With all nations moving along the same path and thus subject to the same forces, trends are exaggerated rather than stabilized.

In 1974-75, the unified business cycle turned down producing the most serious economic crisis since World War II. In 1979, with the bottom of that cycle in the past, most bourgeois analysts (especially in the U.S.) are congratulating themselves for having guided their countries into the fourth year of recovery. Even a casual look at international data, however, suggests that after four years of recovery, world capitalism — far from enjoying prosperity — has entered into a period of growing stagnation. Well into the "recovery" period, unemployment in almost all capitalist countries is at record levels, inflation is rising from an already historically high plateau, industrial production is lagging and investment is weak.[29] With the business press forecasting a normal cyclical downturn in the near future, one can only conclude that capitalists, and those who depend upon them, have hard times ahead.

With markets tightening in DCCs as a result of economic stagnation, Third-World countries pursuing an export-led industrialization strategy will find it increasingly difficult to maintain overall production and export levels. It is quite likely that these countries will experience a sharp decline in earnings and growth with workers and peasants experiencing a simultaneous increase in unemployment and poverty. I am not arguing that transnational corporations will cease to use international subcontracting. On the contrary, I have shown that subcontracting is integral to transnational operations; it may become even more important in a period of economic crisis. It is reasonable to expect, however, that diversified and independent Third-World exports of manufactures to the DCCs will be greatly reduced during the upcoming period of economic stagnation. In other words, while Third-World exports that are tied to the needs of transnational corporations through subcontracting will probably grow, overall Third-World exports of manufactures will suffer.

Trends suggesting this development are already visible. First, data shows that Third-World exports of manufactures have recovered since 1975, but that the gains are concentrated among those countries most committed to subcontracting — Group B. In one example of Group B growth, export values increased by 50% for Hong Kong and South Korea and 30% for Singapore between 1975 and 1976. Most other Third-World nations, however, continue to experience weak export demand.

The second trend suggesting that Third-World countries' overall exports of manufactures will decrease while exports resulting from subcontracting will increase is the growing pressure for protectionism in the international capitalist system. Protectionism, currently taking the form of quotas, special levies, unofficial cartels, and orderly marketing agreements, constrains world trade, especially that of Third-World nations. The impact of protectionism on the Third World, however, tends to be limited to nonsubcontracted goods.

This limitation occurs because when a majority-owned foreign affiliate of a transnational corporation undertakes production, the parent firm uses its political power to prevent any domestic protectionist movement from threatening the trade. Similarly, when an independent Third-World firm undertakes production under a subcontract with powerful retailing corporations or trading divisions of producing firms, these international companies will resist any legislation unfavorable to their trade. When Third-World companies independently produce and directly export goods, however, there is little reason for transnational corporations to oppose protectionism. In fact, there are times when they will promote it so as to create divisions between Third World and DCC workers.

As Sharpston puts it, "This no doubt goes to explain why (despite political resistance) it has been possible for imports to take over nearly all the U.S. market for many consumer electronic products, whereas much more limited penetration of the U.S. textile market (less than 15 percent of consumption of cotton textiles) led to official or "voluntary" quotas on cotton textiles and increasingly on all textiles."[30] This also helps to explain the recent passage of orderly marketing arrangements which limit exports from South Korea's steel, shipbuilding, shoe, and auto industries.

Concluding Remarks

A number of Third-World governments have adopted an export-led development strategy in hopes of achieving rapid capitalist industrialization. I have *attempted to analyze the historical context in which* certain governments adopted this strategy, the rapid expansion of Third-World production and export of manufactures, and the impact of this strategy on Third-World development. I have concluded that although export-led industrialization leads to growth in industrial production and the industrial work force, it will not lead to the creation of an indigenous, self-expanding capitalist economy. Moreover, in the context of the deepening economic stagnation in the core capitalist economies, such an externally based development strategy is likely to produce increased poverty and suffering for workers and peasants in the Third World.

Two final comments are in order. First, conclusions reached in this study should not be generalized to Group A countries. Due to their size and abundant natural resources, Group A countries will probably play a very different role in the world economy than will Group B countries and thus require separate study.

Second, the growth of Third-World manufacturing means the development of a new international division of labor in that it creates an industrial working class in the Third World. This change in the class structure of certain Third-World countries and in international capitalism requires serious study. The new international division of labor may be expanding in response to the needs of transnational capital, but the resulting Third-World industrial working class could become the base for important anticapitalist struggles in the future. With continued economic instability, forecast for Third-World countries, this will indeed become more likely.

Moreover, this new international division of labor produces changes in the political economy of the DCCs. Effects of the international restructuring of production have already been felt by the U.S. working class in declining manufacturing employment, intensification of regional and urban crises, and growing domestic economic instability. Transnational capital has attempted to exploit this situation by encouraging competition and antagonism between Third World and DCC workers. After winning numerous concessions in the Third World, e.g., free trade zones, antiunion legislation, and lack of health standards, capitalists are trying to win similar concessions here in the U.S. The result is a relentless attack on the quality of life and standard of living of workers in this country. Pressure for such concessions to capitalists, in the midst of growing economic stagnation, could result in the development of a strong anticapitalist labor movement.

While capitalists try to exploit the current situation at the expense of workers everywhere, the expansion of the new international division of labor embodies its own contradictions. In fact, as stated above, it appears to be intensifying them in both DCCs and the Third World. In the exploited Third World, global capitalism is enlarging the working class. In the DCCs, the working class is becoming increasingly exploited. Since workers in DCCs and the Third World increasingly share interests in opposing the new international division of labor, the circumstances which now exploit them also strengthen the basis for greater international working-class solidarity.

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NOTES

1. Samir Amin, "Self Reliance and the New International Economic Order," *Monthly Review* 29:3 (July/August 1977) provides a good historical analysis of the impact of imperialism on Third World development. "Capitalism, Underdevelopment and the Future of the Poor Countries," by Thomas E. Weisskopf, *Review of Radical Political Economics* 6:1 (Winter 1972) and the articles in "Case Studies in Imperialism and Underdevelopment," *Review of Radical Political Economics* 3:1 (Spring 1971), are also valuable.

2. Manufactures are defined according to the UNCTAD Standard International Trade Classification (SITC). The *broad* definition used in this paper includes chemicals (SITC 5), basic manufactures (SITC 6), machinery and transport equipment (SITC 7), miscellaneous light manufactures (SITC 8) plus a number of processed food products contained in SITC sections 0-4. The most important are certain processed foods, alcoholic beverages, tobacco manufactures and wood and paper products. Petroleum products (SITC 3) and unworked non-ferrous metals (SITC division 68) are excluded. The *narrow* definition includes only SITC sections 5 to 8 minus SITC division 68.

3. UNCTAD Secretariat, *The Role of Transnational Corporations in the Marketing and Distribution of Exports and Imports of Developing Countries* (TD/B/C.2/197, 16 March 1978) p. 5.

4. UNCTAD Secretariat *Review of Recent Trends and Developments in Trade in Manufactures and Semi-manufactures* (TD/B/C.2/190, 21 March 1978).

5. The United Nations officially includes Yugoslavia and Israel as part of the Third World. They do not, however, include Taiwan in their data collection or calculations. I do not consider Yugoslavia or Israel as Third-World countries in this paper, and therefore have removed them from my calculations. Since the U.N. does not collect data on Taiwan, that country is not included in most calculations.

6. Deepak Nayyar, "Transnational Corporations and Manufactured Exports from Poor Countries," *The Economic Journal* 88:349 (March 1978) p. 61.

7. Because of its Border Industrialization Program, Mexico actually contains aspects of both groups. The program, started in 1965, was designed to speed Mexican development in the areas bordering the United States. It established the border area as a free trade zone with separate administration and regulation. Although I have not made the separation, in terms of my two groups the Mexican border area could be considered a separate geographic area and part of Group B with the rest of Mexico remaining in Group A.

For analysis of the border area see D.W. Baertesen, *The Border Industrialization Programme of Mexico*, D.C. Heath, 1971; "Electronics: The Global Industry," *NACLA* 11:4 (April 1977); "Hit and Run: Runaway Shops on the Mexican Border," *NACLA* 9:5 (July-August) 1975; and Raul A. Fernandez, "The Border Industrialization Program on the United States-Mexican Border, *Review of Radical Political Economics* 5:1 (Spring 1973).

8. Deepak Nayyar, *op. cit.*, p. 81.

9. *Ibid.*, p. 74.

10. For an in-depth discussion of international subcontracting see Michael Sharpston, "International Subcontracting," *Oxford Economic Papers* 27:1 (March 1975).

11. By 1971, one-half of Japanese direct foreign investment was in the Third World and over two-thirds was in manufacturing. According to Deepak Nayyar (*op. cit.*, p. 70), "A large proportion of these investments were directed toward the small Asian economies such as Hong Kong, Taiwan, South Korea and Singapore in order to reap the benefits of abundant unskilled labour and low wage rates . . . Consequently, exports to Japan became a primary function of some Japanese manufacturing investments in Asia. In fact, by 1973, exports back to Japan accounted for nearly 25% of the total sales by Japanese-affiliated manufacturing firms located in Asia; for some industries — clothing (60%) and electrical machinery (30%) — this share was even higher . . ."

12. U.S. Tariff Commission, *Economic Factors Affecting the Use of the Items 807.00 and 806.30 of the Tariff Schedules of the United States* (Washington D.C.: USGPO 1970).

13. "Electronics: The Global Industry," *op. cit.*, and "Hit and Run: Runaway Shops on the Mexican Border," *op. cit.*

14. Michael Sharpston, *op. cit.*, p. 98.

15. The next three countries are Jamaica, Philippines and Haiti.

16. For a more detailed theoretical analysis of export-led industrialization and its impact on Third-World economic disarticulation and underdevelopment, read Clive Y. Thomas, *Dependence and Transformation* (NY: Monthly Review Press 1974); and Alain de Janvry and Carlos Garramon, "Laws of Motion of Capital in the Center-Periphery Structure," *Review of Radical Political Economics* 9:2 (Summer 1977).

17. UNCTAD Secretariat, *Recent Trends*, *op. cit.*, p. 26.

18. Deepak Nayyar, *op. cit.*, p. 62.

19. This arrangement also tends to minimize direct conflict between *transnational corporations and Third-World labor. With no foreign* "owners" of the plant, labor discipline is left to nationals. This helps to explain why nations that are successful subcontractors have such reactionary antilabor policies.

20. Quoting a report from the UNCTAD Secretariat, *The Role of Transnations op. cit.*, p. 11: "An example is that of the marketing of leather footwear for export in Argentina and Brazil. The main feature of this marketing system is the presence in the country of a large number of buying agents, representatives of large United States importing firms, established in the big centres of the shoe industry, who are in control of the marketing operation. 'They buy directly from the numerous firms established in the country for the account of United States principals with specific orders for very large volumes; they indicate the design and styles required, fix prices and delivery dates, control the production process and quality of the product and organize the shipment and the marketing of the footwear exports.' "

21. Michael Sharpston, *op. cit.*, p. 126.

22. Quite often, expansion by transnational corporations represents acquisition or takeovers of existing local firms. This is especially true in Latin America. According to a report issued by the UNCTAD Secretariat, *The Role of Transnationals op. cit.*, p. 15, "A survey of 396 United States and other TNCs operating in developing countries showed that close to 60 percent of the 2,904 subsidiaries existing in the late 1960s had been set up by acquisitions rather than by new investment . . . The electrical industry in Brazil and Mexico provides an outstanding example of the 'denationalization process' (transfer of ownership to foreign companies) of well-established national industries in developing countries through acquisitions of local firms by TNCs." This type of expansion, all too common, certainly does not contribute to Third-World development.

23. Given U.S. transnational concerns with political "safety," repressive Haiti is more attractive than progressive Jamaica. The result is a growing concentration of subcontracting in the former at the expense of the latter.

24. An additional point that needs further research concerns the growing role of transnational banks. In order to export products, competition among Third-World countries has led to the creation of different financing schemes designed to provide easily available and competitive low-cost financing and insurance against foreign trade risks. These schemes require access to funds that most Third-World banks are unable to secure. The result is that transnational banks become increasingly important and powerful in the Third World.

25. For a discussion of free trade zones, see "Free Trade Zones in Southeast Asia" by Tsuchiya Takeo, *Monthly Review* 29:9 (February 1978).

26. "Workers employed in the zone are often subject to special regulations (prohibition of labor disputes, for instance), have to show special passes to enter, and must often undergo body checks when they finish a day's toil. This latter is to prevent 'smuggling' of the zone's products into the workers' own country." *Ibid.*, p. 30.

27. UNCTAD Secretariat, *International Subcontracting Arrangements in Electronics Between Developed Market-Economy Countries and Developing Countries* (TD/B/C.2/144/supp. 1) p. 17.

28. Information on the recession comes from UNCTAD Secretariat, *Recent Trends and Developments in Trade of Manufactures and Semi-manufactures* (TD/B/C.2/1975,11) May 1977.

29. For a more complete description of long term trends in industrial production read Paul M. Sweezy, "The Present Global Crisis of Capitalism," *Monthly Review*, (April 1978) For data on prices and unemployment check recent issues of the OECD *Economic Outlook*.

30. Michael Sharpston, *op. cit.*, p. 131.

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MOD 13

THE IMPACT OF MICROELECTRONIC CHANGE ON DEVELOPING COUNTRIES: THE CASE OF BRAZILIAN TELECOMMUNICATIONS.

Contents:

Abbreviations:

DME - Developed Market Economy
LDC - Less Developed Country
LTC - Local Technological Capability
MEI - Microelectronic Innovation
MNC - Multinational Corporation

MIKE HOBDAY July I983

- ABSTRACT -

Within the literature on Microelectronic Innovation (MEI) and Developing Countries so far little attention has been payed to Telecommunications. This paper argues that although there are major potential economic benefits to be gained as a result of MEI in Telecomms, it is vital that LDC's identify and acquire the appropriate level of local technological capacity to install and expand their Telecomms infrastructure, and to avoid the costs of acute technological dependency. Evidence from Brazil confirms these general propositions showing first, that it was possible to acquire a major capability in digital technology in a relatively short time period, and second that considerable economic benefits are being gained from this investment in micro technology. However, the Brazilian case also demonstrates that without a coordinated intervention and investment on the part of LDC Governments there is little prospect of the potential benefits of MEI in Telecomms being achieved.

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THE IMPACT OF MICROELECTRONIC CHANGE ON DEVELOPING COUNTRIES: THE CASE OF BRAZILIAN TELECOMMUNICATIONS

Introduction:

It is now becoming widely recognised that radical technological change based on digital microelectronic technology will have far reaching consequences for Developing Countries[1]. Although development economists have been slow to turn their attention to the consequences of microelectronic innovation (MEI) for Developing Countries, the diffusion of digital technology in the Developed Market Economies (DME's) has proceeded unabated. Since 1945 the Electronic Goods sector has experienced the fastest rates of growth in output, employment, and trade of any industry in the DME's;[2] the sheer size of the market - estimated at $368b in 1981[3] - and the rapid and sustained diffusion of digital technology into manufacturing processes, commerce, defence, entertainment and important infrastructural industries such as telecommunications, dictates that LDC's seriously consider their objectives and strategies towards microelectronic technology.

If we turn to the limited and very recent literature in this area we find very little agreement on the likely impact of MEI on the Third World. Some observers stress the negative implications and the obstacles to LDC's acquiring and applying this technology to their economic advantage. Current work in this direction points to the possibility of LDC's losing their comparative advantage based on cheap labour as it becomes more profitable for Multinational Corporations (MNC's) to relocate production facilities back to the Developed Countries - a direct result of automation and semiautomation made possible by MEI in process technology.[4] Similarly, it is argued that this rapid technological advance may lead LDC's into a harmful and exploitative relationship of technological dependency on the DME's and the major MNC suppliers of products and technology, just at the point where several LDC's have mastered previous forms of mechanical and electromechanical technologies.[5] In addition, microelectronic technology is seen as 'inappropriate' and unsuited to the needs, skills and factor endowments of LDC's - on one hand the technology is

labour-saving, on the other the highly sophisticated nature of the technology poses almost insurmountable barriers for LDC's in developing indigenous capabilities and competing with the advanced economies. Some authors even forecast a reopening of the 'technology gap' with the bulk of the Third World relegated to pre-microelectronic technology, while the DME's proceed to push the technology frontier further and further away from the grasp of LDC's.[6]

In stark contrast to these gloomy premonitions, other writers are far more optimistic about the prospects for LDC's in acquiring and using micro technology to their advantage. These observers stress the capital-saving nature of digital technology and the potential for small-scale investments.[7] Rather than being inappropriate to factor endowments, the information and science-based skills needed to acquire and utilise digital technology is often abundant especially in the larger LDC's. Furthermore there exists a 'buyers market', not only for microelectronic-based products but also the technology and training needed for assimilating and adapting digital technology.

Accepting that this is an oversimplification of several very complex arguments, it is reasonable to say that so far most of the literature has failed to take sufficient and systematic account of the major differences between the Developing Countries, and equally important, the very different effects in the different sectors experiencing microelectronic diffusion. Clearly it is vital to systematically distinguish between the least developed countries with poorly developed technological and economic infrastructure, and at the other end of the scale, the NIC's and other larger LDC's with well-developed indigenous technological capabilities - and indeed all those groups in between. Plainly, the problems and opportunities posed by MEI will be different for the different groups of countries.

Also, as the various case studies already demonstrate, the economic implications of MEI are very different according to the particular process or industry under discussion. The emerging evidence on the semiconductor component industry, the garment sector, the microcomputer industry, computer-aided design, the capital goods and industrial machinery sector, and our main concern here telecommunications, clearly demonstrate this point.[8]

Given the dangers of generalisation in this field the purpose of this paper is to examine the impact of microelectronic innovation in one essential infrastructural industry in one major Developing Country - the Telecommunications sector in Brazil. Brazil is a particularly interesting case to study due to the considerable Government effort, investment, and apparent success in establishing a viable local Telecommunications (Telecomms) industry based on digital technology, in a remarkably short period of time. Also, as argued later, Telecomms warrant further study in this context, as they represent one of the largest microelectronic sub-sectors, currently constituting about 30% of total output of all electronics-based goods[9] - and yet have recieved very little attention to date.

While most of the paper is concerned with analysing Brazil's transition from electromechanical to a fully electronic Telecomms industry, Part I begins by ouliining the broad industrial and product trends in the world Telecomms market and goes on to argue: first, that modern Telecomms are crucially important to LDC's, and second, that changes brought about by MEI hold major potential, if yet unrealised advantages for Developing Countries. Part 2 examines Brazil's experience with Telecommunications and assesses the Governments performance in establishing: a) a local industrial and technological capacity in digital Telecomms, and b) an efficient, modern, Telecommunications infrastructure. Finally, Part 3 concludes cautiously by pointing/to some wider impications of relevance to other LDC's.

PART I <u>THE POTENTIAL ADVANTAGES FOR LDC'S OF MICROELECTRONIC DIFFUSION IN TELECOMMUNICATIONS</u>

I.I <u>The importance of indigenous technological capabilities in Telecomms and the need for research</u>

It is helpful to view the Telecomms market in terms of two major sectors: first, the demand side comprised of Telecomms services or carrier networks - these are normally provided by Government Post, Telephone and Telegraph administrations (PTT's), and form the basic communications infrastructure of the economy. Second. the equipment supply sector whose demand is derived from the PTT's - this sector is dominated by appx. 20 very large National and Multinational Corporations who account for about 95% of total Telecomms equipment output needed to provide all instantaneous two-way communications, mainly telephone, telegraph, and telex networks.[10]

The equipment supply sector is itself made up of three distinct sub-sectors: first, switching or exchange equipment which constitutes the technological 'heart' of the system connecting electronic signals within and between networks, accounting for roughly 33% of current sales;[11] second, transmission equipment used to carry the signals from one geographical location to another, including traditional methods such as microwave radio relays and underground and sea coaxial cables, and more recent innovations in Satellite technology and optical fibres.[12] The remaining subsector can be described as peripheral equipment and includes all other miscellaneous support hardware such as input/output devices together with telephone handsets and terminals.

Now, while there is a great deal of investigation into the service sector and in particular the relationship between the provision of Telecomms and economic development,[13] there is virtually no research into how modern Telecomms technology can be aquired by LDC's - or indeed, whether it makes economic sense for LDC's to build up local technological capabilites (LTC's) in this area.[14] This is actually quite surprising when one considers that no less than 60 Developing Countries have set up

Government Departments to deal with long-term policy questions such as: a) how to decide on the appropriate level of production and technological capacity; b) how to contend with the major MNC suppliers of equipment and technology; c) how to build up an efficient Telecomms infrastructure; d) how to assess micro-electronic Telecomms and other so-called information related technologies.[15]

This conspicuous lack of economic research is also reflected in the very low economic priority accorded to Telecomms by the major international financial agencies, until at least very recently. As Leff points out, the Telecomms sector is not even mentioned once in Hurni's: The Lending Policy of the World Bank.[16] IBRD lending up to 1978 amounted to $196m, only 1.6% of total loans made, ranking the Telecomms sector next to last in total lending.[17] Similarly overall World Bank lending for Telecomms investments is extremely low accounting for only 2.5% of total lending.[18] In general the major financial institutions view Telecommunications as a 'luxury item' to be considered merely as a component of other 'more important' development projects such as transportation.

A further reason why Telecomms warrant further investigation is the sheer size and growth of the industry especially in the Developing Countries. As mentioned above Telecomms constitute appx. 30% of total output of all microelectronic-based goods; they also represent 10%-15% of world output in Engineering Goods.[19] Last year worldwide sales stood at roughly $47 billion[20] while total book value of investment in the late '70s was estimated at $370 billion[21] - placing Telecomms in the same league as the Computer industry and roughly half the size of the Auto industry.[22] Total sales are forecast to grow to $69 billion by 1987, while the Third World share is expected to increase from its present level of 25% to 30% over the same period.[23] Despite the current economic recession equipment sales are continuing to grow at an overall real average rate of about 8% per annum.[24]

Of course, the large size and rapid growth of the Telecomms market in itself does not justify investment in manufacturing and technological capacity[25] - however, costings by Jequier, although

somewhat dated and sensitive to growth rate and cost assumptions, provide a sound economic principle for choosing between local manufacture and importation.[26] Defining Telecomms demand in terms of lines (which includes all the equipment associated with each telephone line), and assuming an average annual growth rate of 8% over the next 10-15 years, then for a very small Developing Country with less than 100,000 lines currently installed it is probably not economically viable to establish any local production capacity at all. Given the small annual demand of roughly 10,000 the most cost effective solution is to import all the hardware needed, as local production would push the average cost per line far above international prices. Pursuing this logic, small LDC's with approx. 200,000 lines could justify some domestic production of peripheral and some areas of transmission equipment. All larger LDC's such as India, Argentina, Mexico, and Brazil with over 500,000 lines have sufficient local annual demand to warrant a major manufacturing capacity to service their indigenous markets.

As far as technological, as distinct from manufacturing capacity is concerned, there are also strong reasons for the larger LDC's to acquire a major local technological capability -[27] in order to manufacture, install, operate and modify their systems with the maximum efficiency. Whether or not a thoroughgoing technological capacity from Research and Development through to production is desirable depends on factors such as objectives towards competing in international markets, and the percieved need for product innovation capabilities.[28]

However, even the very smallest LDC's justify at least some strategic minimum of technological skills and knowhow to choose and operate the most appropriate system for local needs. One can perceive of a 'ladder' of appropriate levels of technological capacity with R&D at the top, and simple operating skills at the bottom. Whereabouts on this ladder any particular LDC belongs is determined by indigenous market size and export market ambitions. Nevertheless it is important to stress that all LDC's regardless of size need at least the management and software capabilities to be able to purchase, operate, maintain, and expand their systems efficiently to both gain the benefits of a modern communications infrastructure, and to avoid the potential costs of excessive reliance on foreign technology suppliers in terms of foreign exchange payments, and possible costly mistakes in purchasing, planning, installation, operation and so on.

Together with these relatively narrow concerns with the equipment supply sector, in a more profound sense the level of communications technology is vitally important for society at any level of development. As Parker puts it: "The communications technology of a society determines who can speak to whom, over what distances, and with what time delays, and with what possibilities for feedback or return communications. This is the heart of what is meant by social organisation."[29] What modern Telecomms actually do is to dramatically reduce the cost of transmitting information by removing the need to physically transport information, and often goods and people too. As Leff points out modern communications technology also reduces the risk and uncertainty involved in production, investment and other economic activities, while at the same time increasing the amount and quality of market information or signals in the economy.[30]

Without Telecommunications modern economic organisation and administration at individual, firm, market and government levels taken for granted in the Developed Countries, simply would not be possible. Although space precludes a full discussion of these issues it is not difficult to accept Wellenius's proposition that Telecomms are a necessary condition of economic development (although of course not a sufficient one).[31]

What all this means for LDC's currently building up their basic Telecomms infrastructure is a quantum leap in market efficiency and productivity over economic organisation centered around pre-modern communications technology. In fact, the capital-saving nature of modern Telecomms technology was recognised in the mid-19th century by Marx shortly after the invention of the telegraph when he wrote: "The chief means of reducing the time of circulation (ie. of capital) is improved communications. The last 50 years have brought about a revolution in this field comparable only with the industrial

revolution of the latter half of the 18th Century.......... The period of turnover of total world commerce has been reduced to the same extent (ie 70% - 90%), and the efficacy of capital involved in it has been more than doubled or trebled. It goes without saying that this has not been without effect on the rate of profit." (bracketed comments added).[32]

It is for all these reasons that LDC's should identify and acquire the appropriate level of technological capability to install, operate and expand their Telecomms infrastructure. At the same time it is also important that the abysmally low level of research into these matters is also corrected.

I.2 The Potential Advantages for LDC's of Microelectronic Diffusion in Telecommunications

In contrast to the pessimistic arguments mentioned in the introduction, MEI in Telecomms may well favour Developing Countries for 2 main reasons. The first relates to changes in product technology. Essentially digital innovation has enabled the merger of digital computer technology with Telecomms technology. In turn this has greatly expanded the capacity of existing systems and also led to a whole new range of more efficient, less expensive and more flexible products in all major equipment sub-sectors.

In exchange technology massive R&D investment has resulted in solid-state, computer controlled, programmable exchanges. These not only operate more reliably under tropical conditions but are less costly, more efficient and faster than earlier electromechanical Strowger and Crossbar systems.[33]

Similar advantages hold for transmission and peripheral equipment - the major existing microwave, satellite and cable systems can now carry a much greater number and range of signals, at lower cost and higher speed via new methods of digital transmission. Also radically new methods of transmission such as optical fibres are gaining wide acceptance again due to their major cost and reliability advantages over electro-mechanical technologies.[34] There is no doubt among observers as to the economic and technological superiority of digital systems over what are now generally considered to be obsolete electromechanical systems.

The second reason why MEI may favour Developing Countries relates to market structure. Not surprisingly the radical innovations in product technology have had a major impact on the market, increasing both its size and competitiveness New competitors from the aerospace, computer and office equipment sectors have entered the market to challenge the near monopoly of the traditional equipment suppliers. Governments are intensifying this competition by increasingly backing their own national corporations in terms of investment and technological support to ensure their own national status in the so-called information technology sector.[35]

Telecomms are viewed as the 'cutting edge' of modern information technology and massive government support especially in exchange and transmission development is intensifying the already fierce competition among the major corporations. There are currently 16 major Telecomms exchange systems developed at a cost of over $6 billion, competing for uncommitted export markets of only $2-3 billion p.a. As Muller remarks it is highly unlikely that most of these systems will yield a positive return on investment.[36]

Much of this investment is justified on the basis of Third World export markets, as DME markets are usually committed to their own national suppliers - as a consequence LDC's are often in a position to buy the latest digital systems at lower prices than Telecomms administrations in the Developed Countries. When hardware sales are linked to technology sales and establishing production capabilities within LDC's, the stakes are even higher and the open bidding more intense. Indeed, the evidence for India, Mexico and as we see below, Brazil, shows that the major corporations are willing to transfer core technology to remain in LDC markets. In other words technology transfer is being used as a means of inter corporate competition.[37]

To give some idea of the extent of capital saving for LDC's as a result of this technology-based competition in microelectronic systems. Developing Countries installing say 1 million telephone lines today typically pay 3-5 times

less than the industrially advanced countries did 30 - 40 years ago.[38] This is a considerable capital saving by any standards and is the direct result of microelectronic innovation in Telecommunications.

Together with the capital saving advantages of digital systems a further reason why LDC's stand to gain from MEI in Telecomms equipment is contained in the idea of 'leap frogging' older technologies. In contrast to the DME's Developing Countries are not so heavily committed in terms of infrastructural and manufacturing investment to older vintage electromechanical technologies. In fact most LDC's are still in the process of installing and expanding their basic Telecomms infrastructure. This means that unlike the Developed Countries, the Developing Economies are in a position, potentially at least, to bi-pass or leapfrog older technologies and go straight to what are now fairly well established, lower cost, more efficient digital systems.

For LDC's, both large and small, to realise these potential advantages again depends crucially on the local acquisition of technological capabilties in digital based systems. Nevertheless, the local mastery of fully electronic Telecomms technology may not be so daunting as originally thought for 2 main reasons quite apart from the favourable 'buyers market' already discussed. First, the major MNC equipment suppliers are forced to comply with very strict and rigidly defined technical specifications. The major international agencies responsible for regulating and administrating Telecomms specifications, notably the International Telecommunications Union, are willing to provide access to technological knowhow to LDC's at low cost. . This includes not only disembodied specifications and information but also technical training and assistance.[39]
Therefore, in theory at least there is less scope for private appropriation of technology by the MNC's and, in principle, direct access to all aspects of design and operation technology by the Developing Countries.

Second, it also appears that the skills needed to operate, maintain and actually manufacture Telecomms equipment may well be <u>more</u> suited to the types of skill endowments found in many LDC's - rather than inappropriate as suggested by some of the writers referred to in the introduction. Again, the relevant levels of technology and skills will depend on the specific needs of individual Developing Countries; however, for larger LDC's attempting to gain a base in manufacturing technology, a relatively small range of high level design skills is required, coupled with a much wider range of low level assembly skills. This particular skill configuration compares much more favourably with electromechanical technologies which demand a thoroughgoing technological capacity, not only in the manufacture and installation stages but also in basic maintenance. In contrast to these requirements ~~where bottlenecks are frequently found~~ digital systems require lower level skills in the assembly, operation, and especially maintenance stages where the systems are self-diagnostic and need only fairly routine operating expertise. MEI in Telecomms may therefore help overcome existing bottlenecks in available skills rather than present barriers to skill accumulation.

Closely related to these potential advantages concerning local technological accumulation is the modular nature of digital Telecommunications. Digital exchange systems are designed to be modular which means that local networks can be built up gradually from a range of basic modules. At the same time the skills and experience needed to install and develop the systems can also be gradually accumulated.[40] This feature of capital divisibility of fully electronic exchanges is a major advance over the relatively low capacity, inflexibility, and high initial capital outlay associated with earlier electromechanical technologies.

To sum up the basic argument of this very abbreviated account of the impact of microelectronic innovation in Telecomms - it would appear, in theory at least, that very real potential advantages are to be gained from recent developments in digital Telecomms for the Developing Countries. However, the potential economic advantages described here, of:

a) capital saving, b) capital divisibility, c) leap-frogging inferior technologies, and d) the wider economic benefits from establishing an efficient, modern Telecomms infrastructure, can only be gained if LDC's plan and acquire the necessary local technological capabilities. Conversely, the costs of excessive reliance on MNC equipment and technology suppliers, the costs of failing to build up appropriate levels of technological mastery, are clearly very substantial indeed. This in turn implies that despite the general low priority accorded to Telecomms, analysing and planning the accumulation of indigenous technological capabilities must be considered a major component of overall development planning. What follows is therefore a case study of Brazil's attempt to do precisely this.

PART 2: MICROELECTRONIC INNOVATION IN BRAZILIAN TELECOMMUNICATIONS

Of all the industrialising countries over the last 6 years Brazil has placed most emphasis on acquiring an industrial and technological capacity in microelectronic-based Telecomms. Brazil's efforts and investments in developing a digital Telecomms supply sector are part of a wider set of objectives designed to first establish a digital Telecomms infrastructure to support local needs, and second to accumulate a strong local technological capability (LTC) in microelectronics to meet the broader demands of Telematics and other forms of so-called information technology.[41] In order to analyse Brazil's progress in acquiring a base in digital technology section 2.I briefly describes the poor state of the supply sector before 1974 and goes onto examine the objectives of the new incoming Government in terms of a) establishing a modern Telecomms infrastructure, and b) aquiring a major industrial and technological capacity in digital Telecomms technology. Section 2.2 attempts to provide a measure of overall Government success in meeting these objectives by assessing events in both the public and privately owned equipment supply industry, and finally by examining Brazil's progress in establishing an efficient, modern Telecomms infrastructure which of course is the purpose of all these efforts.

2.I Telecomms Problems pre '74 and the Government's Technology Policy response.

Before the change of Government in March 1974 severe problems beset Brazil's Telecomms industry. Although some progress had been made towards rationalising and expanding the Telecomms network since the Ministry of Communications was established in I967, the equipment supply sector showed no such signs of coordinations and planning. Four major MNC's owned and controlled virtually the whole of the equipment industry;[42] this, in itself would not necessarily have posed problems had the MNC's developed their industry and technology according to Brazil's broader development needs and objectives. However, this was not the case; like many other industries following the general trend of rapid, unchecked economic expansion during the I967-74 Brazilian 'economic miracle', the Telecomms industry had entered a period of crisis.[43]

By I974 the industry was facing acute problems of over-capacity, falling internal demand, growing financial debt, together with redundancies and factory closures.[44] In spite of very high and rising technology and equipment import costs the local MNC subsidiaries had developed very little in the way of core exchange and transmission technology - indeed, the major technology contracts show that the subsidiaries played a passive role in technology transfer, only recieving those elements of technology required to support local assembly of equipment.[45] By the mid '70s Brazilian-based industry was not only foreign owned and controlled but lacked any autonomous capacity for research, development or even product or process innovation. In other words the industry exhibited the classic symptoms of severe and costly technological dependency - high technology payments, little indigenous technological capacity, and little control over the direction and pace of industrial and technological development.

With the takeover of the Medici Government in I974 a major shift in overall industrial and technology policy occurred. The new Government was committed to reversing the trend of foreign ownership of Brazilian industry and determined to increase local industrial and technological capabilities in key sectors such as Telecomms.[46] In I976 the Government decided not only to acquire a thoroughgoing LTC in Telecomms but in fact to gain the most sophisticated, microelectronic technology as part of Brazil's longer term strategy of establishing a major LTC in digital Telematics technology.[47] In order to meet these broad objectives the Ministry of Communications planned first, to gain control of the ownership of the industry; second, to gain effective management control of the industry; and third, to establish a dynamic local capacity in digital technology - independent of foreign suppliers.

The ultimate aim of the new Government was to accelerate the expansion of an efficient and dependable Telecomms infrastructur accross the length and breadth of the country. Tariffs were to be restructured and rationalised across regions in order to recover operating and capital costs, plus further earnings of up to I2% to provide investment for additional expansion.[48] Post '76 policies also provided for expansion based on the latest micro-electronic technology; by this deliberate strategy the Government intended to gain the potential benefits described earlier of bi-passing intermediate electromechanical technologies and providing services based on digital systems.

As far as the equipment supply sector was concerned the Ministry of Communications oulined a detailed policy of establishing local ownership and control of existing enterprise while at the same time building up a major LTC in digital Telecomms systems. In order to meet the critisisms that Brazil was too acquiescent to foreign capital the Government introduced import-substitution protection to foster and stimulate the development of a National Telecomms industry based upon LTC accumulation. Through the purchasing power of TELEBRAS (Telecomunicacoes Brasileira S.A.) local manufacturers were to be encouraged to provide the equipment and materials for the new electronic networks. Other policies were also adopted to ensure the development of Brazilian human capital mostly through local training of electronics engineers and technicians. Central to these objectives was the setting up of a major R&D capability to master the very latest, 'ffontier' microelectronic technology accross all major areas of Telecomms exachange and transmission equipment, in order to 'leap frog' the relatively less efficient, low capacity and more expensive forms of technology.[49]

Government policy of LTC accumulation was therfore to be carried out by a 'two pronged' strategy of: first, directly developing core technology via local Government R&D efforts (mainly through the R&D centre under TELEBRAS located at Campinas-CPQD); and second, indirectly by ensuring the local MNC manufacturing subsidiaries transferred ownership and key technology from their parent companies abroad. By establishing National control over the pace and direction of industrial and technological developments in the supply sector, self-sufficiency in Telecomms was aimed for. Within this overall inward-looking industrial strategy, dependence on foreign Corporations had no place at all. Import controls, industrial subsidies and regulations were therefore introduced to meet these explicit and uncompromising Government objectives.

2.2 Assessment of Brazil's Technological Progress in Telecomms

2.2.I Private Sector Developments

If we turn to events in the private sector it does appear

that the Brazilian strategy has succeeded in bringing about: first, a transfer of equity to local enterprise; second, a transfer of management and technological control to local industry; and third, a substantial transfer of microelectronic-based technological capacity from parent plants to former subsidiaries located in Brazil.

In order to precipitate the transfer of equity control the Ministry of Communications insisted that only firms majority owned by Brazilian capital could tender for the large new digital contracts on offer after 1976. Companies wishing to compete for these orders also had to ensure that the bulk of inputs were supplied locally within a very short, fixed time period.[50] Table I shows that during the first two effective years of this 'Brazilianisation' directive sales by foreign corporations fell from 90% to 40% of total, while the corresponding share of local industry increased from only 10% to 59%.

Table I: Sales of National Corporations and Foreign Affiliates in the Telecommunication Industries, 1978-1980.
(percentages)

	National Corporations[I]		Foreign	
	Small/Medium	Large	Affiliates	TOTAL
Year:				
1978	10	-	90	100
1979	7	39	54	100
1980	34	25	41	100

I/ as defined by Regulation No. 622.
Source: Ministry of Communications/TELEBRAS
From SSI (1983) p51

Superficially at least it does appear that the TELEBRAS procurement policy has substantially shifted ownership from foreign to National capital, by creating the conditions by which large Brazilian capital groups could take over the industry in the latter half of the '70s.

Of course equity control by no means ensures control over management and technology, therefore we also need to examine the extent to which the affiliates have restructured their organisations in order to assimilate and develop modern Telecomms technology.

Turning to the largest affiliate, Ericcson do Brasil (EDB), with roughly 40% of market share a major reorganisation did indeed take place to facilitate the local development of technology. In order to win the new contracts on order the company was forced to restructure their management organisation from one centred around production activities to one centred around technological activities.[51] Brundenius and Goransson show how a new Technology Directorate was set up with an entire division devoted to exchange technology, while other divisions deal with transmission, peripheral and informatics development. For the first time privately owned industry located in Brazil is now developing and manufacturing microelectronic-based Telecomms systems.

The seriousness with which developing LTC's is taken by local industry is also underlined by the new technology contract negotiated between EDB and the parent company in 1978. Unlike earlier contracts this agreement called for a thorougoing capability in all major areas of Telecomms technology to be actually located in Brazil. All relevant aspects of embodied, disembodied, and what can losely be termed 'techno-managerial' knowhow, were negotiated for by EDB in conjunction with TELEBRAS. Eventually all the vital technology and knowhow needed to develop and manufacture the Ericcson AXE-10, SPC digital exchanges were transferred.[52]

Interestingly, the technology costs to Brazil were substantially lower than the major earlier contract, even though the terms of the new agreement were clearly superior. Overall payments amounted to appx. 60m SEK ($11m) over a 5 year period compared with an official figure of 93m SEK or $18m over the previous 1972-77 contract. In fact, total technology payments over this earlier period were closer to $52m with some estimates suggesting even this figure was an understatement.[53] The largest value component of the new technology contract was direct training for for Brazilian engineers and technicians both in Brazil and Sweden; other major components included technical assistance and disembodied technology in the form of specifications, computer software and other consultancy services.

To sum up. the evidence clearly indicates a major shift towards local management and technological development as a

direct result of Government intervention mainly through the purchasing power of TELEBRAS. In order to win the major new business in microelectronic systems (plus the promise of further orders) the MNC's were forced to locate all the essential hardware and software technology necessary for research, design, engineering, manufacturing and installation of digital equipment within National boundaries. Quite clearly this reorientation did not simply occur, but was the means by which the affiliates were able to remain in the Brazilian market and compete with other suppliers. In other words local technological accumulation has proved decisive as a means of corporate competition between the local MNC subsidiaries.

2.2.2 Public Sector Technological Developments

Turning to direct Government investment by TELEBRAS it is also clear that considerable progress has been made towards gaining National self-sufficiency in electronic-based Telecomms. As mentioned earlier the efforts of TELEBRAS have to be viewed within the broader, longer-term objectives of establishing a microelectronic Telematics infrastructure - however, one can already point to major advances in leap-frogging earlier technologies and in actually shaping Brazil's information-technology infrastructure from the outset.

The 'backbone' of indigenous technological progress in digital Telecomms is the major R&D centre located at Campinas (CPqD). Table 2 illustrates TELEBRAS's commitment to R&D, with investment increasing steadily from $26m in 1977 to $52m in 1981. Most of this investment is directly in CPqD. By 1981 CPqD housed 403 regular employees with a further 300 contracted in from Universities, research institutes and other corporations. Of these employees 243 (60%) are local University graduates, while a further 141 (36%) carry out intermediate level technical operations - again mostly graduates. In the near future CPqD plans to employ over 500 full-time electronics engineers constituting a major R&D capacity by any international standards.[54]

Already CPqD has achieved very significant progress in all the main areas of Telecomms technology. Beginning with exchange equipment, a family of advanced electronic systems

Table 2: Investments in R&D by TELEBRAS, 1977-1981 (millions of dollars)[a/]

Year	Investments R&D Expenditure	Fixed Assets[b/]
1977	20.1	5.4
1978	22.0	6.7
1979	31.3	25.0
1980	32.1	22.1
1981	30.8	21.4

Source: TELEBRAS. From SSI (1982) p.53
a/ Exchange rates: $ Cr. 65.5 (Jan, 1981)
b/ Includes land, construction of buildings and acquisition of real estate and equipment.

have already been developed utilising the most sophisticated TDS - SPC switching technology.[55] The aim here is not only to compete in design and quality with internationally available products, but also to develop equipment more suited to the types of climate and telephone traffic conditions found in Brazil and other Developing Countries. So far CPqD has produced a wholly Brazilian designed, developed, and manufactured, high capacity public exchange system which is currently undergoing field tests. Low capacity exchanges and line concentrators are also being tested in the field following development and manufacture by CPqD.

Local transmission system development is equally ambitious. Under CPqD's programme a complete optical fibre transmission system, employing the latest laser and multiplexor technology, has been successfully designed and is now under experimental use in Rio de Janeiro. Also central to Brazil's wider information-technology objectives is a transmission project based on digital satellite communication technology. Again all the necessary components needed for linking the major cities are being developed and manufactured locally; the first wholly Brazilian built satellite is due to be launched next year to provide a wide range of Telematics services such as data transmission, alongside telephone and TV transmission.

Import dependence has also been reduced in a broad range of periferal technologies designed and developed in Brazil. Commercial production has begun in telephone dial and keyboard handsets with output standing at 410,000 in 1981. Among the many other items based on information-technology developed by CPqD are modems, videotext terminals, and other vital hardware and software essential for National and International data communications.

A measure of Brazil's success to date in local production and technology is the steady decline of Telecomms equipment imported by TELEBRAS:

Table 3 Telecommunications Equipment Imports by TELEBRAS 1976-1981 (Millions of Dollars)

Year	Value
1976	100
1977	58
1978	33
1979	33
1980	30
1981	19

Source: Ministry of Communications/TELEBRAS
From SSI (1982)

As Table 3 shows the total value of TELEBRAS imports has fallen from $100m in 1976 to only $19m in 1981. Government estimates show that TELEBRAS's own system will supply 15% of the local market this year while 50% of future orders are now being reserved for CPqD's system.

Brazil has clearly made considerable progress in reducing technological dependence and catching up in the Telecomms field. Given this performance to date in bridging the technology gap, Brazil's expressed intentions of becoming a major international supplier of Telecomms equipment in the future must be taken seriously.[56]

2.2.3 Performance in Establishing a Modern Telecomms Infrastructure

As noted earlier the ultimate success of all these efforts has to be judged against Brazil's performance in building up a modern Telecomms infrastructure. Again even a cursory glance shows that Brazil's achievements over the '70s in expanding and improving the Telecomms network has indeed been impressive. Table 4 below gives some idea of the magnitude of TELEBRAS's overall investment in Telecomms amounting to the huge total figure of $7.8 billion of the 6 year period 1976-1981.

Table 4: Investments by the TELEBRAS System, 1976-1981
(Millions of Dollars)

Year	Value 1/
1976	1,790
1977	1,540
1978	1,340
1979	1,280
1980	890
1981	950

Source: Minisry of Communications/TELEBRAS. From SSI (1982) p.52

As a consequence of this heavy investment, TELEBRAS has achieved a massive expansion in basic Telecomms coverage. If we examine the position in the mid 60's Brazil had less than 2 telephones per 100 population amounting to only 1.3 million telephones covering a total population of 74 milli[on]. Telex coverage reflected this poor state of Telecomms infrastructur[e] with less than 1000 terminals serving the whole of Brazil's domestic and international needs. In general Telecomms services were inefficient and inadequate with modern transmission systems extending to only 4 of the major cities. At this time one major foreign coroporation was responsible for 68% of installed telephones with no less than 800 other small private companies responsible for a generally fragmented, unorganised and technologically backward Telecomms service.

Since 1970 domestic telephone coverage has risen dramatically

with a 6 fold increase from only 1.3m to 8.4m in 1981. This in effect has raised the number of telephones per 100 population from only 2 to roughly 6.8 compared with an overall average for LDC's of about 1 telephone per 100. Internationally, Brazil now compares well with most other Developing Countries in Latin America, Asia and Africa. Today the domestic network efficiently covers 3641 (88%) of Brazil's municipalities including all major towns and cities. Over the 1980s the Ministry of Communicatio[ns] plans to further increase coverage from the present level to around 20m.

International telephone traffic has also witnessed a remarkable expansion rising from only 4m international calls in 1969 to 343m in 1980, with a growth rate of 20% in each of the last 5 years. Direct dialing now connects Brazil with 56 other Nations. Telex traffic has experienced equally rapid growth since the mid '70s - by the end of 1980 Brazil's fully automated public telex network serviced 535 major localities supported by 53 domestic telex exchanges utilising over 43,000 terminals.

Underlying this impressive growth in Telecomms traffic is a vastly improved and expanded transmission network. The main form of domestic transmission is terrestial line-of-sight microwave relays which connect up all the States and most towns. More remote regions are serviced by troposcatter microwave, short wave radio, and satellite transponders leased from INTELSAT.[58] Brazil is now one of the largest Third World users of satellite transponder facilities which are increasingly being utilised for domestic as well as international coverage. One of the main reasons for Brazil's entry into developing satellite technology is to overcome the inflexibility of services rented from INTELSAT; by developing LTC's in satellite technology it is intended that dependence on INTELSAT will be reduced, and the 'digitalisation' of Brazil's Telecomms infrastructure will be able to proceed unhindered.

Alongside microwave and satellite transmission over the latter half of the '70s major advances have been made in underwater coaxial systems, mainly for intercontinental Telecomms coverage. Two main systems called 'BRACAN' and 'BRUS', developed jointly with the National Telephone Company of Spain and AT&T respectively, link Brazil with Europe and the U.S. with further high capacity transmission facilities.

As far as meeting the demands of modern Telematics technology is concerned sophisticated and comprehensive maritime and airline services have already been established. A public data communications service (TRANSDATA) began operating in 1980 and now covers 300 localities with over 4000 terminal points. Although it was necessary to import some of the technology for TRANSDATA much of the equipment was developed and supplied locally. A further digital network for storing, manipulating and transmitting data at low cost and high speed (SICRAM) is now open for public use. An international banking data communications service is also now currently under contract and due to come into operation in the near future.

Finally it is worthwhile mentioning Brazil's entry into other Telematics areas still regarded as experimental in most of the Developed economies. A Videotext system enabling the digital transmission of data through the existing telephone network is currently being tested in Sau Paulo and due to begin commercial operation this year. Another project, TELETEX, transmits data via TV signals while both systems use TV sets to display information to end users. Also a public international electronic mail system is already operating in Rio de Janeiro and Sau Paulo and is due to be extended to other major cities with a facility for domestic electronic mail.

In short since the early '70s Brazil has not only achieved a dramatic improvement in basic Telecomms coverage, but has also made considerable progress in establishing a range of other services considered to be at the frontier of Telematics technology in the advanced market economies.

CONCLUSIONS AND WIDER RELEVANCE TO OTHER DEVELOPING COUNTRIES

The case of Brazilian Telecommunications clearly conforms to the more optimistic views of the potential for LDC's to acquire and use microelectronic technology to their advantage. There can be little doubt that Brazil has made considerable progress towards achieving the potential advantages in Telecomms which I attempted to outline in Part I. However, as stressed earlier, it would be quite wrong to generalise from the experience of a major industrialising country like Brazil, in one microelectronic sector albeit one of the largest — if not the largest in the world economy. Whether or not similar potential lies for other LDC's in other 'downstream' microelectronic sectors is a matter for further study. The following conclusions are therefore offered in a tentative spirit with a concern to be aware of the limitations of country specific case study evidence of this kind.

What the evidence does seem to demonstrate is: first, that it was possible for Brazil to gain a major capability in microelectronic-based Telecommunications. Second, considerable present and future benefits are to be gained from this investment in local capacity in digital technology. Third, none of Brazil's achievements occurred through market mechanisms but were the direct result of deliberate and imaginative Government policy designed to ensure an indigenous capabilty in microelectronic technology. It is helpful to briefly consider any wider relevance of these three main points in turn.

Brazil's success in building a major industrial and technological capacity in digital Telecomms in such a short period of time, is indeed a remarkable achievement which may hold lessons for other larger LDC's such as India and Mexico which appear to be pursuing a similar path. In order to ensure that the major MNC's did in fact transfer core technology it was necessary for the Government to insist that digital technological facilities were set up within Brazil's national boundaries. Mainly through the purchasing power of their own Telecomms administration, TELEBRAS was able to exploit the already fierce technology-based competition between the MNC's to ensure the development of technological capabilities in Brazil. As Part I tried to show, this potential may well be available to other LDC's currently purchasing equipment and technology.

In addition, and despite the absence of a semiconductor manufacturing capacity - or indeed any other major microelectronic-based industry to draw technological expertise from - public sector enterprise was able to develop from scratch, the technological capability to design, develop, and manufacture equipment at the very frontier of digital technology. It is also evident that R&D efforts are well integrated to local industrial production and not marginalised, or confined to high level scientific research of doubtful industrial relevance. Government enterprise is forecast to supply 15% of total Brazilian Telecomms requirements this year, and as we saw has successfully designed, developed and is now installing digital exchange and transmission equipment; this locally produced equipment is not only capable of meeting domestic Telecomms demand, but also the wider, longer term Telematics objectives of the Government. Whether or not other major LDC's require such a substantial R&D facility is of course a matter for overall development planning. However Brazil's record of achievement in Telecomms demonstrates the potential for other semi-industrialised countries to acquire a National technological capacity in digital technology via the Telecomms industry, and therefore should prove both instructive and encouraging.

As far as costs and benefits are concerned it clearly is not possible to conduct a formal cost-benefit analysis when dealing with the dynamic, long term benefits from National investments in technology - many of these benefits are external to the enterprise and occur in the future. However, some of the potential gains from establishing a local tecnological capacity in Telecomms described in Part I have already been achieved. As we saw, Brazil's major R&D facility has ensured a shift from a position of acute and costly technological dependency to one of dynamic local industrial and technological development. Local enterprise

is now capable of developing and supplying exchange and transmission equipment more suited to Brazil's specific climatic and geographical circumstances. The confidence gained by investing in digital technology was also central in ensuring the MNC's actually transferred genuine core technology, and in substantially reducing the costs of this technology to local enterprise. The obvious benefits from local production in terms of foreign exchange savings, employment expansion, and improved economic and technological integration with other industrial sectors are already beginning to be realised.

Although these types of private and social benefits are very difficult to quantify, and have to be set against the financial investment costs, we can also point to the considerable economic and social advantages from actually establishing a comprehensive, efficient and modern Telecomms infrastructure. Since 1975 Brazil has vastly improved and expanded their domestic and international Telecomms networks, and at the same time prevented any possibility of any so called 'technology gap' from occurring. By accumulating information related technology, principally through microelectronic Telecommunications, Brazil has ensured its continued participation in the many economic activities which now depend so heavily on information technology.[59] The possibility of using the local Telecomms industry to accumulate a National capacity in information related, microelectronic based technologies is of obvious interest to other larger industrialing countries.

Turning to the role of Government, the final point to stress, of relevance to larger and smaller LDC's is that none of Brazil's achievements could be described in any way as 'automatic' or the result of market forces. On the contrary Brazil's successes were the direct result of the very 'visible hand' of Government policy and strategy in translating a political will into an economic and technological reality. Without a sustained and innovative effort on the part of Government the backbone of local technological progress, the R&D center at Campinas, simply would not exist. Nor would the pressure on the private sector to transfer and develop the core technology needed to design and manufacture digital systems suited to Brazil. Without an offensive technological and industrial strategy there is also good reason to doubt that the major infrastructural advances since 1975 would have been achieved.

This conspicuous success of Government technology policy in reducing dependence on imports of equipment and technology, and producing locally a range of Telecomms equipment at the very frontier of digital technology is a very encouraging sign for other major industrialising countries. Those concerned with the possibility of widening technology gaps should also note the speed and success of Brazil in laying the foundations for a microlectronic-based information technology infrastructure. Brazil's experience also emphasises the arguments put foreward earlier that even for the very smallest and poorest LDC's to gain any benefits from installing and operating an efficient Telecomms Infrastructure, and to avoid the costs of excessive reliance on MNC's and consultancy experts, it is vital to identify, plan, and then ensure the relevant local technological knowhow is accumulated. In fact, if there is one overriding lesson to be learned from the Brazilian experience it is that without a clearly defined and concerted Government policy, without a deliberate effort, investment and indeed risk on the part of Government - there is little prospect of Developing Countries gaining the potentially considerable advantages made possible by microelectronic advances in Telecommunications.

- NOTES -

1. See Hoffman (1981) and (1982) for comprehensive discussion

2. Parthasarathi (1978) p.IV

3. Hoffman (1982) p37, sales figures.

4. See for example Rada (1982) and Kaplinsky (1982)[c]

5. Similar fears are expressed by Communications writers such as Cruise O'Brien and Helleiner (1980).

6. Notably Kaplinsky (1982)[b], see also in the Communications literature Mitchell (1978), (1978)[a], and (1976) also Clippinger (1977) and (1977)[a].

7. In the technology literature see Soete (1983) - similar optimistic views are expressed by prominent Communications observers such as Clarke(1981) and Pelton (1981).

8. See respectively, Rada (1982) Hoffman and Rush (1982), Tigre (1982), Kaplinsky (1982)[c], UNCTAD (1982) and Part I below for Telecommunications.

9. O.E.C.D. (1982) p12

10. Jequier (1977) p266

11. OECD (1982) p12

12. Again comprising roughly 33% of sales, IBID

13. Hudson et al (1981) provide a review of this literature and a useful bibliography.

14. A notable exception is Jequier (1977) who focusses mainly on the channels of technology transfer between DME's and LDC's rather than the local accumulation of technology.

I5. Spero (I982)

I6. Leff (I980) p2, notes.

I7. Hudson et al (I98I) p2.

I8. Hudson (I98I) pI59.

I9. OECD (I982) pI2.

20. Source A.D. Little Consultancy Agency, cited in Newsweek, (I983)

2I. Muller (I982)p2.

22. Jequier (I977) p205.

23. As note 20, both figures in constant I979 US dollars.

24. Pelton (I98I) p2I0.

25. For an examination of the crucial distinction between manufacturing and technological capacity see Bell and Hoffman (I98I) and Bell (I982).

26. For additional details see Jequier (I977) pp222-4.

27. Again, see note 25.

28. For instance Brazil has justified a thoroughgoing LTC on the basis of future export markets and the need to modify equipment for internal use. (Discus ed below).

29. Quoted in Hardy (I980) p280.

30. Leff (I980)

3I. Wellenius (I977) p294-5.

32. Cited in Rosenberg (I982) p46, ~~mm~~ Coral, Vol 3

33. See POEU (I979) for a description of early electro-mechanical systems through to fully electronic equipment, and the clear technological and economic superiority of digital equipment.

34. Some remarkable reductions in transmission and peripheral costs are detailed by Muller (I982) ppI9-27.

35. The rapid growth and importance of this sector is clearly documented by the OECD (I98I)

36. Muller (I982) ppI06-7.

37. For details of technology transfer to India see Electronic Times (I982). For Mexican case see Behrman and Wallender (I976) chapter 6.

38. Jequier (I977).

39. ibid

40. Details of the modularity of Digital equipment are given by the POEU (I979) pI7.

4I. 'Telematics' or 'Informatics' are part of a wider range of information-based technologies centred around microelectronic, or semiconductor technologies and made possible by the fusion of Telecomms and digital computer technology. The purvasion of these technologies throughout many economic and social activities in the DME's is documented by OECD(I98I) and (I98I)[a]. Brazil's role at the forefront of the LDC's in this area is described by Spero (I982).

42. The dominance of MNC capital in this sector was therefore even more pronounced than in the overall electrical equipment sector identified by Newfarmer (1979) and Epstein and Mirow (1977) - approximately 77% of total.

43. For a lucid account of the economic crisis which followed the 1967-1974 'Miracle' period see Wells (1979).

44. See Brundendenius and Goransson (1982) for details of the high technology costs, redundancies and falling profits at this time.

45. ibid.

46. For details see Dahlman (1982) and Wells (1979).

47. Pelton (1981) p.218

48. The following details are from SSI (1982).

49. An account of the wide range of intermediate technologies for Britain is presented by POEU (1979) p.17

50. SSI (1982)

51. This section draws heavily on Brundenius and Goransson (1982). I concentrate on EDB for two reasons: first, EDB is representative of the equipment supply market being the market leader with roughly 40% of sales throughout this period; second, the absence of any other definite information regarding the other major MNC's.

52. Again for further information see Brundenius and Goransson (1982). SPC (stored programme controlled) refers to a switching system whose internal operation is performed by a computer.

53. Brundenius and Goransson (1982).

54. For additional information see Pelton (1982). The following information on CPqD is from SSI (1982).

55. TDS (Time Division Switching) is the most advanced form of digital exchange technology.

56. Pelton describes Brazil's ambitions towards competing with/and overtaking the US and Japan in the future (1981) p.219.

57. The following details are from SSI (1982) and Pelton (1981) unless otherwise stated.

58. INTELSAT is the International Satellite Organisation responsible for providing 60% of the worlds overseas Telecomms traffic.

59. Unfortunately space has precluded a full discussion of the purvasion of information technology in the Develpped Countries. Some of the main areas include international investment, marketing, data processing, banking, air and sea traffic, together with many other areas of production and commerce. Again see note 41 above.

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Also, the speed at which modernization makes progress in China is of significance.

(7) In this context, it would be meaningful to come out with a number of scenarios on the future of the Asia-Pacific region with alternating changes in a number of premises, such as the speed of China's modernization. The author believes it is high time such scenarios be framed up, but again this is not a subject under the theme of this paper.

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THE ELECTRONICS INDUSTRY IN MALAYSIA
— Issues in Transfer and Development of Technology —

K. C. Cheong *and K.C. Lim**

I. Introduction

Malaysia, as in many developing countries, is placing heavy emphasis on industrialization for two main reasons – to generate productive employment and, to diversify the economic base of the country to make it less dependent on exports of primary commodities such as rubber, tin, oil palm and timber. It also offers prospects of a transfer of technology which should lead to upgrading of skills and the quality of capital so crucial to economic development.

However, in more recent years, there has been increasing concern that the existing pattern of industrialization has not lived up to all its promises. First, despite the high rates of growth of industries, the generally capital-intensive nature of these industries has resulted in less than satisfactory rates of growth of employment. Secondly, whatever employment that is generated has exacerbated existing inequalities in income, and compounded the dualism already existing in the economy.[1] Thirdly, the transfer of often inappropriate technology from abroad has inhibited the development of local technological capability and therefore perpetuated technological dependence on the

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1. A concise account of why this occurred both within and between countires is given by Yotopoulos and Nugent (1976), Chapter 14. See also Adelman and Morris (1973) and Chenery and Syrquin (1975).

yeloped countries.[2] Further, there are economic costs associated with e operations of multi-national corporations (MNCs), which have been couraged to establish as a result of the government policy of at-acting foreign investment.

The study of the extent of transfer of technology by these ablishments and of their linkage with the local economy to Malaysia therefore very important, and because the electronics industry is garded as a high-technology one and one dominated by MNCs and reign-owned enterprises, it is appropriate that it has been selected as ase study. Its choice is also justified by its size and phenomenal rate growth relative to other industries in the manufacturing sector[3] able 1). At the international level, Malaysia is after Singapore, the gest exporter of electronics components and electrical goods.

In Section 2, major characteristics of establishments making up sample providing data for analysis are described. The methods and ts of transfer are dealt with in the next section, while the relation-p between technology transfer and the development of local abilities via employment of personnel and research and development xplored in Sections 4 and 5. Evidence on diffusion of technology ough primary-ancillary linkages and through labour turnover is ussed in Sections 6 and 7, and last but not least, major implications policy are drawn in Section 8.

II. Characteristics of Surveyed Establishments

This study is based on data collected from as survey of electronics electrical companies in Peninsular Malaysia in August 1980.[4] A l of 60 establishments was covered in the survey, and out of these, provided information on the transfer of technology and primary-llary relationships. Fourteen are wholly-owned subsidiaries of Cs, 10 are foreign-owned non-MNCs, and the remaining 8 are local blishments. (Table 2).

'or a comprehensive discussion of the methods and effects of technology transfer, see iteward (1979).

/ery little of substance has been written on the Malaysian electronics industry. An early ccount is Federal Industrial Development Authority (1971). The most comprehensive tudy is that of Lim (1978), while Lester (1981) examined specific issues in the transfer of echnology.

he study of the electronics industry is part of a large study covering six industries: extiles, cement, electronics, wood, plastics and steel.

Table 1

The Growth of the Electronics Industry, Peninsular Malaysia, 1973-1978

Indicator	1973	1974	1975	1976	1977	1978
No. of Establishments: No.	83	107	122	138	170	181
% Income	—	28.9	14.0	13.1	23.2	6.5
Value Sales: US$ Million	122.1	266.1	275.6	435.5	602.3	890.8
% Increase	—	117.9	3.6	58.0	38.3	47.9
No. of Paid Employees: No.	22,562	26,672	30,098	46,559	49,518	60,957
% Increase	—	18.2	12.8	54.7	6.4	23.1
Salaries and Wages Paid: US$ Million	11.9	26.4	28.9	47.1	65.8	87.7
% Increase	—	121.8	9.5	63.0	14.0	33.3
Value of Exports: US$ Million	11.0	86.5	116.8	204.8	345.4	652.5
% Increase	—	686.4	35.0	75.3	68.6	88.9
No. of Establishments as % Total No. of Establishments in Manufacturing	5.1	6.0	6.6	7.1	7.6	7.5
Value of Sales as % of Sales of Total Manufacturing	5.5	7.9	8.9	14.9	11.8	14.5
No. of Employees as % of Total No. of Employees in Manufacturing	12.4	13.7	14.2	19.2	18.8	21.0
Value of Salaries as % of Total Value of Salaries in Manufacturing	7.7	13.7	12.8	16.4	18.0	19.1
Value of Exports as % of Total Value of Manufactured Exports	2.3	11.1	13.9	19.1	27.1	36.3

Sources : Malaysia: Department of Statistics: *Monthly Industrial Statistics* and *Annual Statistics of External Trade, Peninsular Malaysia*

Table 2
Ownership and Nature of Production of Surveyed Establishments

Industry	Number of Establishments	Ownership	Nature of Production
Electronics			
MNC Subsidiaries	12	4 American	(3 Components (1 Industrial
		4 Japanese	(3 Components (1 Consumer
		1 Italian	Components
		1 German	Components
		1 British	Industrial
		1 Canadian	Components
Foreign	5	1 American	Components
		2 Japanese	(1 Component (1 Consumer
		1 French	Component
		1 Swiss	Industrial
Local	6	Malaysian	(4 Consumers (2 Components
Electrical			
MNC Subsidiaries	2	2 Japanese	(1 Consumer (1 Industrial
Foreign	5	1 Australian	Consumer
		1 Hong Kong	Consumer
		1 British	Industrial
		2 Origin Not Stated	(1 Consumer (1 Industrial
Local	2	Malaysian	Consumers

Electronics establishments are more labour intensive compared to electrical goods establishments; the component electronics establishments are the most labour intensive, employing an average of 966 workers per establishment. The capital investment of electronics establishments range from $0.32 million to $9.09 million as shown in Table 3. The range is smaller for electrical goods establishments ($0.46 million to $2.73 million).

Table 3
Employment and Capital Investment of Surveyed Establishments

Industry Group	Average Employment	Capital Investment (US$ Million)	
		Average Value	Range
Electronics			
Components	966	$2.84	$0.23 – $3.18
Industrial	657	$1.77	$0.32 – $5.91
Consumer	539	$3.41	$0.23 – $9.09
Electrical	339	$1.74	$0.46 – $2.73

III. Methods and Costs of Technology Transfer

The transfer of technology to developing countries can take various forms, depending on several factors, including the complexity of the product and production techniques transferred, the transfer environment in the donor and recipient countries, the absorptive capacities of the recipient firm, and the transfer capability and profit-maximizing strategy of the donor firm.[5] Generally, the transfer of technology may take the following forms: turnkey contracts, joint ventures, technology licensing agreement, management contracts and public knowledge.

In the early stages of a country's industrialization, most foreign enterprises usually adopt the turnkey arrangement where there is direct

5. See for example, Baranson (1970), Cooper and Sercovich (1971), Stewart (1979) and United Nations (1973; 1975).

and complete transfer of technology, from the plant construction stage to the production stage. In almost all cases the foreign companies themselves provide all the technical and managerial resources, by arguing that technological leadership and reputation for quality and efficiency cannot be maintained unless they have full control of the operation of the plant.

In recent years, joint ventures have been encouraged as an alternative to MNC subsidiaries. In effect, however, transfer of technology through joint ventures is almost similar to the turnkey method because the suppliers of process technology maintain considerable control over the operation of the new production facilities, since the local partner has limited technological and/or management know-how needed to organize the new project.

Where there is minority foreign capital participation in joint ventures, the transfer of technology may take the form of technology license agreements whereby the technology seller reaps substantial returns in the form of fees, royalties, and profits from the sales of components and intermediate products. From the buyer's point of view, a license is regarded as the quickest way of acquiring a given technology and as a means of establishing a monopoly position in that particular technological field.

Local entrepreneurs who wish to establish a manufacturing concern but do not possess the necessary technological know-how usually buy the patents or know-how from foreign manufacturers. In such cases, the foreign seller also takes charge of various phases of establishing an enterprise. Again, the local entrepreneurs usually have limited experience with licensing agreements and little knowledge of the technical implications and cost of the various parts of the technological package, and are therefore at a disadvantage vis-a-vis suppliers of patents when prices are negotiated.

A final source of acquiring technology is from suppliers of machinery and equipment or through technical and commercial publications (books and journals). Suppliers of machinery and equipment normally provide advice on the operational technology pertaining to such equipment, particularly where the technology is not very complex and where no proprietary techniques or processes are involved. In some cases, the machine supplier may even provide training for local personnel or continue to guide the plant operation beyond the normal start-up and take-over stage. Payments for such services may be provided for separately or are built into those for machinery and equipment. Usually it is the small locally-owned enterprise producing standardized and technologically unsophisticated goods that rely solely on technical assistance from the suppliers of machinery. The medium sized and large local companies that produce highly differentiated branded goods tend to use license agreements.

Table 4 shows the major method of technology transfer used in the surveyed establishments. All the electronics and electrical MNC subsidiaries are turnkey projects, and it is not suprising that although most of them have been established since the mid-1970s, they are still heavily dependent on their parent companies for equipment and machinery parts, professional technical personnel, training of local personnel, and even marketing support. All the twelve electronics and two electrical MNC affiliates still rely solely on the parent companies for machinery, equipment, and spare parts; nine of them still depend heavily on the assistance of foreign professional technical personnel; and six of them send their local personnel for training in the parent companies.

None of the surveyed foreign establishment depend on the turnkey method of technology transfer. Of the ten foreign electronics and electrical establishments, five electronics and two electrical companies are joint ventures. All the five electronics joint ventures rely on the foreign partner for capital equipment, foreign professional technical personnel and training of local personnel overseas. Two of the establishments pay royalties (one for use of patents and one for technical assistance) to the foreign partner's parent company. The two joint-venture electrical establishments differ in their reliance on foreign partners. The Japanese establishment relies heavily on the parent plant i.e. it imports capital equipment, it depends on foreign technical personnel and its personnel are trained by the parent company. In addition, this establishment also pays royalty to the parent plant for the use of patents. The other electrical establishment, Australian-owned, obtains its capital equipment from its parent plant. It does not depend on foreign technical personnel and its local personnel are trained in Malaysia. However, it has to pay royalty to the parent company for the use of patents (brand name).

Three foreign electrical establishments obtain their technology through licensing arrangements. All these three establishments pay royalties to the parent plant for technical know-how and require the assistance of foreign professional technical personnel. In addition, two of these also pay royalties for the use of trade marks.

Seven out of the eight local establishments rely on licensing agreements for their technology; the r[illegible]ning [illegible] rely [illegible]n p[illegible]

Table 4
Methods of Technology Transfer
among Electronics and Electrical Goods Establishments

Type of Establishment	Total Number of Establishments	Transfer Arrangement: Turnkey	Licensing Arrangement	Joint Venture	Equipment Suppliers/Public Knowledge
Electronics					
MNC Subsidiaries	12	12	–	–	–
Foreign[a]	5	–	–	5	–
Local	6	–	5	–	1
Electrical					
MNC Subsidiaries	2	2	–	–	–
Foreign[a]	5	–	3	2	–
Local	2	–	2	–	–
Total	32	14	10	7	1

a : Defined as an establishment with over 30% foreign equity participation. The rest are classified as local.

Table 5
Average Cost of Technology Transfer
among Electronics and Electrical Goods Establishments

Type of Establishments	Importation of Capital Equipment	Foreign Professional Technical Personnel	Training of Local Personnel Overseas	License Technical Know-how From Foreign Firms	Royalty Payments For Use of Patents
Electronics					
MNC Subsidiaries	1,574.1	126.4	109.1	–	65.5
Foreign	386.8	124.1	15.5	19.6	852.7
Local	36.4	6.4	–	22.7	45.5
Electrical					
MNC Subsidiaries	–	4.1	5.5	–	–
Foreign	95.5	35.0	44.1	34.6	76.4
Local	–	15.9	–	–	–
Total	584.6	59.6	48.2	28.2	198.6

knowledge as well as on equipment suppliers. Under the licensing agreements, one establishment pays royalty for the use of capital equipment, and another pays fees for engaging foreign professional technical personnel. The license arrangements for the other five establishments include contracts for the supply of capital equipment as well as foreign professional technical personnel. One of these also pays royalties for the use of patents.

Some of the establisnments surveyed provided data on money costs incurred by the methods of transfer described above. These costs are computed on a per establishment basis in Table 5. MNC subsidiaries in electronics spend on average much more on the imports of capital equipment than do other establishments. Foreign electronics establishments, with an average of US$386.8 thousand are a distant second. Overall, the next most important costs are royalty payments for the use of patents, averaging US$198.6 thousand per establishment. The bulk of this however comes from payments by foreign electronics establishments, averaging US$852.7 thousand. Consistent with other studies of technology transfer, costs associated with stationing of foreign personnel here and the training of local personnel are relatively unimportant. What can be noted, however, are the higher than average expenditures of foreign electronics firms for the former and MNC subsidiary electronics firms for the latter.

IV. The Employment of Foreign Personnel

It is impossible for Malaysia to develop electronics and electrical industries without importing foreign technology. However unless there is a concurrent development of local technical capability, the country will remain permanently dependent on the foreign suppliers, and there will be no opportunity to develop alternative technologies which are more appropriate in the Malaysian context. An important way to develop these is the training of local personnel to replace expatriate personnel in the establishments.

Table 6 shows the number of establishments which are still employing foreign technical personnel and the firms that are providing training programmes for the local personnel. As expected, all the fourteen MNC subsidiaries and nine out of the ten foreign establishments employ foreign technical personnel; in addition, six out of the eight local surveyed establishments also employ foreign technical personnel.[6]

Table 6

Technical Personnel in Electronics and Electrical Goods Establishments

Type of Establishments	Total Number of Surveyed Establishments	Employment of Foreign Technical Personnel	Training of Local Technical Personnel	*NO* Technical Training Programmes	*NO* Foreign Technical Personnel
Electronics					
MNC Subsidiaries	12	12	6	6	—
Foreign	5	5	5	—	—
Local	6	4	2	4	2
Electrical					
MNC Subsidiaries	2	2	1.	1	—
Foreign	5	4	5	2	1
Local	2	2	1	1	—
Total	32	29	18	14	3

At the management level, however, foreign presence is only moderate. Table 7 shows that apart from Japanese establishments, with 9.2% of management personnel being expatriates, the representation of foreigners was small. One explanation could be differences in management methods[7], but differences in production activity may be just as important.

Table 7
Number of Expatiates in Management of Electronics and Electrical Goods Establishments: By Product Type and Ownership

Product Type/Ownership	Mean Number of Expatriates Per Establishment	Share of Expatriates in Management Personnel (%)
Product Type		
Consumer Products	5.4	7.8
Components	2.6	2.2
Industrial	3.0	7.9
Ownership		
Malaysian	3.5	6.0
Japanese	5.0	9.2
U.S.	1.5	0.8
European	1.5	4.3
Others	3.0	5.8

Although foreign technicians (mainly engineers) are costly[8], they are needed for various reasons. However, while the fact that almost half of the twenty-one establishments which responded state that the main reason is that their technical expertise is required suggests a shortage of local personnel with equivalent qualifications, only two establishments are explicit about this (Table 8). Nor were other reasons given entirely convincing. While four establishments list 'technological innovation required for new products' as a major factor, assembly operations are not known for product development. The same number state simply that company policy is responsible for this.

Table 8
Reasons for having Expatriates among Electronics and Electrical Goods Establishments

Reason	Number of Establishments	Percentage Distribution
Technological Innovation/New Product	4	19.0
Company Policy	4	19.0
Technological Expertise Required	10	47.6
Training of Staff for Eventual Transfer	1	4.8
Lack of Local Skill or Qualification	2	9.6
Total Responding	21	100.0

Significantly, half of the number of surveyed electronics MNC subsidiaries do not provide overseas training for their local technical personnel. On the other hand, all except one foreign electronics and electrical establishment do. Local companies also send their technical personnel for overseas training. Overseas training is normally for a short period of time – between one to six months at the parent plant or partner company. MNC subsidiaries spend between US$5,455 to US$127,272 a year for training locals overseas, while foreign establishments spend between US$22,727 to US$5,455 a year for such purposes. No corresponding data have been obtained from the surveyed local establishments. Only three out of the eight surveyed local establishments have overseas training programmes for their technical personnel. This is not surprising because, as mentioned earlier, most of these companies have acquired their technologies through licensing arrangements, and because most of the technical knowledge can be acquired from the suppliers of machinery and from the foreign profes-

6. An MNC subsidiary employs between one to thirteen expatriates while a foreign establishment has between one to nine foreign technical experts, and a local establishment employs between one to three foreign technical personnel.
7. See Kojima (1878).
8. The costs of maintaining expatriate personnel range from between US$49,091 to US$227,273 a year for MNC subsidiaries and between US$34,901 to US$454,546 a year for foreign-owned establishments.

sional personnel engaged by these companies, there is less need to organise overseas training courses for their technicians with a foreign firm also acts as a factor which hampers the training programmes of the local companies.

V. Research and Development Activities

Local research and development (R and D) is also essential to the development of local technology. A proper R and D base serves not only to adapt foreign technology but also to assist in its absorption and in its exploitation by further technical development.

Table 9 shows the extend of local R and D activities undertaken by the surveyed companies. Eleven out of the fourteen MNC subsidiaires are fully dependent on their parent plants in R and D work. In fact the R and D activities of all MNCs are located in the home country, with the results disseminated to their subsidiaries all over the world, partly because of the economies of scale in R and D work and partly

Table 9
Research and Development Activities of
Electronics and Electrical Goods Establishments

Type of Establishments	Reliance on Foreign Source		
	Full	Partial	None
Electronics			
MNC Subsidiaries	9	3	–
Foreign	5	–	–
Local	4	2	–
Electrical			
MNC Subsidiaries	2	–	–
Foreign	3	2	–
Local	1	1	–
Total	24	8	–

because of the need to safeguard trade secrets. In three cases some design and development takes place locally but the basic research is still done in the parent plants. Foreign establishments are generally dependent on foreign sources in R and D work; eight out of the ten surveyed establishments are fully dependent on their partner companies, while two (electrical goods establishments) are partially dependent. The local establishments are heavily dependent on public knowledge such as journals as well as instructions from the machine manufacturers. The reliance on these sources indicates the generally low level of technology at which the local establishments operate, and the concentration on manufacturing products for which technology is widely known. The self-development of technology is costly and uneconomical for the relatively small local establishments while the lack of trained engineers and technicians also act as a deterrent. Nevertheless, three local establishments have some form of R and D work at a relatively low technological level (e.g. copying and modifying designs).

The primitive stage of R and D work in the electronics and electrical establishments in Malaysia is further indicated by the fact that even in establishments which have R and D, the amounts spent on such activities have been negligible. Expenditures on R and D range from between US$6,818 to US$27,272 a year. The number of staff engaged in R and D varies from one to twenty. Furthermore, as mentioned above the type of R and D is relatively simple. For example, a foreign electrical establishment is at present involved in the testing of automatic defrost (frost-free) refrigerators while a local electrical establishment acquires new technology by dismantling foreign-produced goods. Other R and D activities of the survyed establishments include the drawing up of new designs, research on quality improvement and adjustment of specification to local market needs (or to suit individual customer's tastes).

An analysis of the surveyed establishments regarding investment in R and D in Malaysia reveals the following: (a) when the establishment is only involved in the manufacture of some components for inclusion in an assembly, most of which has been imported from the parent plant or partner company, there is practically no investment in R and D; (b) where a foreign establishment establishes a plant in the country mainly to enjoy tariff protection, no R and D work is undertaken, the technology is simply transferred from the parent or partner plant with the minimum possible expenditure; and (c) establishments which are really interested in the long-term objective of producing for an expanding domestic market as well as a potential export market considworthwhile to set up R and D work.

VI. Primary-ancillary Relationships

The transfer of technology involves not only its transfer from an investing (developed) country to the host (developing) country but also the diffusion of technology in the latter. One of the main arguments against free trade zones and the electronics industries of developing countries in the absence of linkages which bring about this diffusion.[9] We have attempted to test the validity of this hypothesis by identifying various linkages which may exist between local ancillary establishments. The responses from up to twenty-three establishments are presented in Table 10.

The lack of relationship is clear from this table. Only three out of twenty-three establishments invest in ancillary establishments, only two supply raw materials and two second personnel. At the same time, seven out of ten establishments report giving no assistance whatever to ancillary establishments which supplied materials while a similar percentage of establishments reports no plans for making arrangements with local ancillary establishments. Among the latter, the view is expressed by five establishments that arrangements may be made in future only if the technology of local ancillary establishments improves.

Parts and components supplied by ancillary establishments are listed in Table 11. While there is some variety in the range of products, most do not involve a high level of technology, and it certainly cannot be said that "the sophistication (of the ancillary establishment) is more advanced than the current domestic industrial sector could support on its own" (Lester (1981), p. 33).

The figures shown in Table 11, however, did not imply the lack of primary-ancillary relationships in general, as a much larger number of establishments had ancillary suppliers abroad. Table 12 shows that the majority of electronics establishments import all parts and components from abroad.

The majority of these cite the fact that these materials were not available locally as the most important reason for imports (84.6% of all

9. See, for instance, United Nations Conference on Trade and Development (1980). Lim (1978) came to the conclusion that "inter-industry linkages between multinational electronics firms and domestic supporting industries are non-existent in Malaysia and miniscule in Singapore so far . . ." (p. 464).

Table 10
Indicators Showing the Lack of Primary-Ancillary Relationship among Electronics and Electrical Goods Establishments

Indicators of Relationship	Type of Establishments (No.)				Total No. as % of Respondents
	Consumer Products	Electronic Components	Others	Total	
Investment in Ancillary Firms	2	1	0	3	13.0
Supply of Raw Materials to an Ancillary Firm	2	0	0	2	12.5
Personnel in Ancillary Firms	1	1	0	2	13.3
No Assistance to Ancillary Firms	3	3	1	7	70.0
No Increase in Ancillary Arrangements	9	1	2	12	66.7

respondents) (Table 13). This includes, in effect, the local non-availability of materials able to meet the required technical specifications. The fact that four establishments cite the poorer quality of local materials was further evidence of this. Further Table 14 indicates that most establishments irrespective of product group are of the view that the products of local suppliers are poorer than those imported. Three establishments also report that imports are cheaper.

Table 11
Parts and Components Obtained from Local Ancillary Establishments

Type of Establishment/Ownership	Parts & Components
Electronics	
MNC Subsidiaries	Electrical Parts
Foreign	Packing Material; Plastic Parts; Polystyrene Parts; Printed Materials; Paint
Local	Resistors; Chassis
Electrical	
MNC Subsidiaries	TV Cabinets; Speakers; Packing Materials; Condensers
Foreign	Resistors; Plastic Cabinets; Antenna Coils; Packing Materials; Diodes
Local	Kettle Handles

The unavilability of supplies and materials locally suggests that an important way to improve buying arrangements of establishments is to set up more ancillary establishments here. The latter should, however, employ qualified personnel and, indeed, one establishment would like to see better qualified personnel in existing establishments. Three establishments also feel that government duties on materials are excessive and should therefore be reduced.

Table 12
Relationships between Electronics Establishments and Local and Foreign Ancillary Establishments

Type of Establishments/Ownership	Number of Establishments: All Parts and Components Imported	Number of Establishments: Some Parts Obtained From Local Ancillary Establishments	Total
Electronics			
MNC Subsidiaries	11	1	12
Foreign	3	2	5
Local	4	2	6
Electrical			
MNC Subsidiaries	1	1	2
Foreign	4	1	5
Local	1	1	2
All Establishments	24	8	32

VII. Mobility of Labour

Technology is diffused also by the movement of workers trained by electronics establishments. Evidence elsewhere again indicates that this is unlikely to be significant.[10]

Among the establishments surveyed, two factors make for diffusion along these lines. These are, as shown in Table 15, (1) a high proportion of workers 'trained on the job' in the plants, and (2) high levels of labour turnover and high vacancy rates. However, the first factor is less favourable than first appearance would suggest. The majority of the workers are reported to be trained on the job, while only an average 12.4% have been trained out-of-plant. It is likely that the 'training' provided to the former is low-skill, rudimentary, and often specific to the industry. Therefore, few skills are learned among unskilled and semi-skilled workers. A small proportion, the skilled workers, have been able to acquire some skills however.[11]

With respect to labour turnover, it was not possible to obtain quantitative estimates of the number of workers who have found work outside the electronics industry, but personnel officers in the surveyed establishments are almost unanimous in the view that most workers move within the industry. Also most of those who move are unskilled and semi-skilled workers, there being little evidence of the same degree of mobility among professional and technical personnel.[12]

VIII. Conclusions and Policy Implications

Despite arguments to the contrary, the general conclusion from this survey is that technological transfer among electronics and electrical establishments in Malaysia is extremely limited. Components

10. Cohen (1975) in his study of establishments in Korea, Singapore and Taiwan found that workers in MNCs tended to move between foreign firms so that skills acquired were not passed on to the domestic industrial sector (p. 111).
11. Lim (1978) came to a similar conclusion regarding the electronics industry in Singapore (p. 463). The opposite conclusion is arrived at by Lester (1981). He found that the vanity of job tasks performed was large, and "these job tasks and groups were not tied to the peculiarities of the electronics industry sector but were widely applicable to any modern manufacturing sector" (p. 22). Since his sample consisted of technical personnel and skilled workers, however, his findings did not conflict with ours.
12. Lim (1978) goes even further, arguing that "on account of higher wages and better service conditions in MNCs vis-a-vis domestic establishments, there is even a possibility of personnel moving from the latter to the former" (p. 464).

Table 15
Qualitative Aspects of the Labour Force of Electronics Establishments: Training and Labour Turnover

	Percent of Workforce (%)			
	Consumer Products	Electronic Components	Industrial/Communications Equipment	Total*
Training				
On the Job, In Plant	65.7	98.2	87.0	81.9
Off the Job, In Plant	12.0	14.0	0.8	9.4
Out of Plant	11.9	3.8	23.6	12.4
Labour Turnover				
Recruitments	29.8	36.0	22.6	31.3
Resignations	20.3	28.6	22.5	24.9
Vacancies	19.8	9.7	13.3	13.1

* : Includes establishments classified under 'Others'.

Table 13
Reasons for Outside Purchases and Imports of Parts, Materials and Supplies Cited by Electronics and Electrical Goods Establishments

Reasons	Type of Establishments (No.)				Total No. as % of Respondents
	Consumer Products	Electronic Components	Others	Total	
Reasons For Outside Purchases					
Not Available Locally	7	7	1	15	78.9
Purchases of Parent Company	0	0	1	1	5.3
Better Quality	2	0	0	2	10.5
More Stable Supply	1	0	0	1	5.3
Reasons For Imports					
Not Available Locally	9	9	4	22	84.6
Cheaper	1	1	1	3	11.5
Pioneer Status	0	0	1	1	3.9
Total Number of Establishments	10	10	6	26	100.0

Table 14
Comparison between Foreign and Local Supplies to Electronics and Electrical Goods Establishments

Local Supplier is: –	Type of Establishments (No.)				Total No. as % of Respondents
	Consumer Products	Electronic Components	Others	Total	
Poorer	5	5	2	12	70.6
Equal	0	2	1	3	17.6
Better	1	1	0	2	11.8

establishments are largely 'turnkey' factories completely dependent on foreign technology, even though joint-venture agreements predominate among consumer products and industrial/communications equipment establishments. The direct monetary costs to the establishments of various forms of transfer are therefore minimal when compared with the value of sales. An exception is the cost of importing foreign machinery which is sizeable but to the extent that turnkey operations *necessitate* these imports, this strengthens rather then weakens our arguments about the absence of technology transfer.

This does not mean that economic costs to the host country of technology transfer are insignificant. The costs associated with actual royalty payments for instance represent but a fraction of other hidden costs like those associated with transfer pricing[13] (underpricing of exports and the overpricing of imports), restrictions on access to technology and other impediments to the growth of local technological capability.

The absence of research and development in the establishments surveyed is entirely consistent with the picture of lack of technology transfer discussed above. Complete or partial reliance on foreign (usually parent company) research resources, reported by a majority of surveyed establishments, strengthened the oligopolistic positions of multi-nationals as proprietors of technological knowledge and permitted 'packaging' of such knowledge by these companies when transfer takes place.

Further, the very limited linkages with local ancillary establishments also implied that transfer of technology via this channel is not significant. Among these ancillary establishments, most are engaged in the manufacture of low technology products or are machine shops. A third symptom of the lack of local skill or qualifications is the dependence on expatriate personnel. However, many of the surveyed MNC subsidiaries and foreign companies are providing overseas training for their technical staff, nevertheless, such training is only for a short duration of between one to six months at the parent plant or partner company. Most local companies however do not provide such training facilities.

While there has been widespread criticism of the activities of MNC's and their negative role in the transfer of technology, much has also been made of 'learning effects' or the transfer of 'general industrial

13. Stopford and Wells (1972) found that the extent of transfer pricing depended upon the type of enterprise in existence. Joint ventures paid less for inputs than did MNC subsidiaries (pp. 161-2).

experience' by these enterprises.[14] Data on these are hard to find, however, and our study does suggest that there be some learning effects in the electronics industry.

From the policy point of view, however, the crucial question is less whether these effects exist but more whether they could have been greater had other industries been established. More generally, it can be said that the issue of whether the transfer of technology is a major issue of government policy depends on the specific objectives of the policy. If the interest of the government is purely to maximize employment, then the electronics industry must be favourably considered. However, if, as is the case, the development of an industrial sector dynamic enough to generate appropriate technologies and possessing widespread linkages with other sectors is a principal objective, then the case for the electronics industry, particularly components assembly, cannot be a very strong one. Given, however, that present commitments to the industry cannot and will not be withdrawn in the foreseeable future, what policy options are available?

Various policies to improve the bargaining position of, and the benefits accruing to the host countries have been suggested. These have been classified into[15]: (1) those to control and improve the terms on which foreign technology is transferred, (2) those to promote local technological development, and (3) those to promote inter-industry linkages. Some of these have been implemented with varying degrees of success in industrialising countries.

In the case of Malaysia, however, dealings with foreign and multinational companies have so far been confined only to matters regarding tax rates or concessions, local equity participation, repatriation of profits, tariff protection, import quotas and so on. These is insufficient consideration regarding the types of technologies these companies will be introducing to the country and how these may be diffused, the decentralization of management decisions, participation in national research and educational activities and linkages with local industries.

Policy to encourage local technological development should include (1) measures to protect local technological development by allowing only selective import of foreign technology, and (2) provision of the required infrastructure and other incentives to encourage local

14. See Lester (1981) and Helleiner (1973). Kojima (1978) restricted this mode of transfer to Japanese enterprises, arguing that American MNC's, by producing goods which are technologically too sophisticated for the LDC's in which their plants are sited, do not permit much opportunity for learning.
15. Stewart (1979), p. v.

technological development. Under the latter, incentives may be given to establish R and D laboratories; fiscal incentives could also be given to a company to carry out research "cost-free". In addition, these R and D laboratories may be encouraged to deal with problems of the local environment, participate in local university research programs and enter into joint research with local research institutions such as SIRIM (Standards and Industrial Research Institute of Malaysia).

Realistically and in the short-run, however, the leverage of the host country vis-a-vis the MNC's may be quite limited, and the effectiveness of the suggested policy measures cannot be guaranteed. Over a longer period, as the country's industrial base is more firmly established, and as increasing incomes make for a larger domestic market, a shift in the types of industries to be encouraged will be desirable, indeed necessary, as Malaysia's comparative advantage in low wages is progressively eroded.[16]

16. An emergent labour shortage situation has already been reported in manufacturing. Population and labour force projections estimate that a general ageing of the population will become noticeable in the beginning of the next century.

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THE IMPACT OF GENETIC ENGINEERING ON INDUSTRY*

prepared by

UNIDO Technology Programme

* Based on "Impacts of applied genetics: micro-organisms, plants and animals", Office of Technology Assessment, United States Congress, Washington, D.C., United States of America (OTA-HR-132, April 1981).

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Abbreviations

AA	amino acids
EOR	enhanced oil recovery
FDA	Food and Drug Administration (United States)
ICI	Imperial Chemical Industries
NIH	National Institutes of Health (United States)
ppm	parts per million
R+D	research and development
rDNA	recombinant deoxyribonucleic acid
SCP	single-cell protein

CONTENTS

PREFACE

UNIDO's programme of technological advances aims at sensitizing developing countries to the potentials and limitations of emerging technological advances and strengthening their capabilities to make use of such advances, whenever appropriate. The programme includes activities in the field of genetic engineering and biotechnology. A meeting of eminent experts in this field was held at Vienna from 4 to 6 February 1981 and, following one of the meeting's recommendations, a group of experts prepared a report on the establishment of an International Centre for Genetic Engineering and Biotechnology. Future activities envisage inter alia national-level workshops on the potentialities of genetic engineering and biotechnology for industrial development for industrialists, scientists and policy-makers of developing countries.

In order to provide developing countries with information on ongoing assessments of genetic engineering and its impact on industry, the secretariat of UNIDO considered it useful to prepare a paper based on "Impacts of applied genetics: micro-organisms, plants and animals" (April 1981) prepared by the Office of Technology Assessment, United States Congress, United States of America, but covering industrial sectors only.

The paper has been prepared by the UNIDO secretariat for the purpose stated earlier and does not constitute an official paper of the Office of Technology Assessment.

INTRODUCTION

In recent years, biotechnology in general, and genetic engineering in particular, have shown that they could contribute to filling some of the most fundamental needs of humankind.

Biotechnology is the industrial process which utilizes living organisms or their components. Genetic engineering concerns the directed manipulation of the genetic material itself. This process, which involves recombinant DNA (rDNA) and the chemical synthesis of genes, could increase the size of the gene pool for any one organism, thus making available genetic traits from diverse populations. Genetic engineering can help improve the speed, efficiency and productivity of biological systems. It uses a technique, at the laboratory level, which allows modification of the hereditary functions of the cell. The population of the altered identical cell that grows from the first unchanged micro-organism is, in turn, used for various industrial processes. It is within this framework that the impacts of applied genetics in the various industries is examined.

Regardless of the industry, the same three preconditions must be met before genetic technologies can become commercially feasible. They are:-

(a) a useful biological product;
(b) a useful biological fermentation approach to commercial production;
(c) a useful genetic approach to increase the efficiency of production.

All three conditions are interrelated and can be met in any order. The demonstration of usefulness, however, can begin with any of the three. Thus, the commercial potential varies with each product. In some cases, the usefulness is already shown and the usefulness of genetic engineering must be proved. In others, genetic engineering makes production at the industrial level possible, but the market is not established, and in others, feasibility is the major problem.

The time horizons (5, 10, 15, 20 years) for the commercialization of various products using genetically engineered micro-organisms are presented in an annex. The estimated value of these products is $24 billion.

I. FERMENTATION TECHNOLOGIES

A. General View

The oldest user of biotechnology is the food industry where micro-organisms are used to ferment food and beverages. It is estimated that approximately 700 companies throughout the world use fermentation technologies to produce a variety of products. Originally, fermentation technology involved the use of bacteria to make yoghurt or of yeast to ferment wine. Recently, however, fermentation technology utilizes cells from higher plants and animals under growth conditions known as cell or tissue culture. In all cases, large quantities of cells with uniform characteristics are grown under defined controlled conditions.

In its simplest form, fermentation consists of mixing micro-organisms with a solution and allowing the components to react. The more sophisticated large-scale process requires control of all the variables so that fermentation proceeds smoothly and the process can be reproduced with the identical quantities of starting material.

Generally, products obtained from fermentation can also be produced chemically and less often, could be isolated by extraction from whole organs or organisms. A fermentation process is attractive when the analogous chemical process requires more steps to complete the conversion. Furthermore, a chemical process would invariably proceed via a series of intermediates which have to be extracted and purified in turn before they are used in the next step. Whereas during fermentation, all steps take place within the micro-organisms.

B. Enzyme Technologies

Fermentation by live cells has provided the basis for designing fermentation processes based on isolated enzymes. A single enzyme situated within a living cell is needed to convert a raw material into a product. Now if the enzyme responsible for the conversion is identified, it can be extracted from the cell and used in place of a living cell. The purified enzyme functions exactly as the cell, breaking down the raw material in the absence of a micro-organism. An enzyme which can convert a raw material to a product inside the cell could also do this outside the cell.

Although more than 2,000 enzymes have been discovered, less than 50 are of industrial importance. However, two major features make them attractive; their specifity and their ability to function under relatively mild temperature and pressure conditions.

At the moment, both whole cells and isolated enzymes are being used and it is difficult to predict which will be more prominent in the future. Although both have their advantages and disadvantages, the role of genetic engineering in the future of the industry will be partly determined by which is chosen. With isolated enzymes, genetic manipulation can increase the supply of enzymes whereas with whole organisms a variety of manipulations is possible in constructing more productive strains.

C. The Relationship of Genetics to Fermentation

Applied genetics and fermentation technology are closely linked because isolating a suitable species of micro-organism is the first step in developing a fermentation technique. Until recently, geneticists had to search for an organism that already produced the desired product. However, through genetic engineering micro-organisms can be made to produce substances beyond their "natural" capabilities. The most striking advances have appeared in the pharmaceutical industry where human genes have been transferred to bacteria to produce insulin, interferon, growth hormone, etc.

The current industrial approach to fermentation technologies addresses two problems. Initially, whether a biological process can produce a particular product and, secondly, what micro-organism has the greatest potential and how the desired characteristics can be engineered for it. Finding the desired micro-organism and improving its capability has now become a fundamental and important aspect of the fermentation industry.

II. THE PHARMACEUTICAL INDUSTRY

A. General View

The pharmaceutical industry,which was the last to adopt traditional fermentation techniques, has been the first industry to extensively use rDNA and cell fusion techniques. Genetic engineering for the production of pharmaceuticals has two goals:

(a) to increase the level or efficiency of the production of pharmaceuticals of proven or potential value;

(b) to produce totally new pharmaceuticals and compounds not found in nature.

The first goal has had the strongest influence on the industry. It has been almost axiomatic that if a naturally occurring organism can produce a pharmacologically valuable substance, genetic manipulation can increase the output.

B. Potential Uses of Molecular Genetic Technologies

Polypeptides (proteins),which are the end-products of genes,include peptide hormones, enzymes, antibodies and certain vaccines. Producing them has been the goal of most recent work in genetic engineering. However, it is merely a matter of time before complex non proteins like antibiotics can be made through rDNA techniques.

1. Hormones

Hormones are the messenger molecules that help the body co-ordinate the actions of various tissues. The most advanced application of genetics today is in the field of hormones. Attempts at synthesizing human peptide hormones (e.g. insulin and growth hormone) gave genetic engineering the necessary impetus in that field.

There are four technologies for producing polypeptide hormones:

(a) extraction from human or animal organs, serum or urine;
chemical synthesis;

(b) production by cells in tissue culture;

(c) production by microbial fermentation after genetic engineering.

One major factor in deciding which technology is best for which hormone is the length of the hormone's amino acid chains. The low molecular weight peptides can be chemically synthesized relatively easily. Thus, the chemical synthesis of hormones up to 32 amino acids (AA) in length can be competitive with those derived from biological sources. Since polypeptide hormones can also be synthesized genetically, the practicality of doing so must be assessed on a case-by-case basis. The main criteria necessary for assessing the practicality of one method vis-à-vis the others are:-

(a) cost of raw materials;

(b) the cost of separation, purification and removal of contaminants;

(c) labour and equipment costs;

(d) costs and suitability of comparable materials gathered from organs or fluids obtained from animals or people.

(a) <u>Insulin</u>

Insulin is composed of two chains (A and B) of amino acids. Work on the genetic engineering of insulin has proceeded quickly and both chains of human insulin have been synthesized. It is worth noting that while 2,000 l of fermentation brew would yield 1 g. of purified insulin, 16 g. of animal pancreas would be required to produce the same amount. Current research is under way to increase the yield (the average diabetic requires 2 mg of animal insulin per day).

Genetically synthesized insulin, however, is not yet ready for commercial use. The drug has to be approved by the United States Food and Drug Administration (FDA) and marketed as a product as least as good as the insulin product produced conventionally. The clinical rationale behind using a human insulin is due to the differences in structure among insulins produced by different species. It remains to be seen how many patients will be better off with human insulin and whether the side-effects of diabetes, retinopathy and nephropathy will be minimized.

~~(b)~~ <u>Growth Hormone</u>

Growth hormone is another polypeptide hormone awaiting approval by the FDA. It is a single chain polypeptide, 191 to 198 AA in length and is essential for postnatal human growth. The secretion of insulin is stimulated by growth hormone and the action of growth hormone in the body depends on the presence of insulin. Human growth hormone, apart from correcting dwarfism, is also found to be of therapeutic value in other areas, namely:-

(i) senile osteoporosis (bone decalcification);

(ii) other nonpituitary growth deficiencies such as Turner's syndrome;

(iii) intrauterine growth retardation;

(iv) bleeding ulcers that cannot be controlled by other means;

(v) burn, wound and bone-fracture healing.

The preparation of micro-organisms with the capacity for synthesizing growth hormones has been achieved.

(c) Other Hormones

Other polypeptide hormones where rDNA synthesis is being attempted include:-

(i) Parathyroid hormone (84AA) - may be useful for bone disorders, e.g. osteoporosis;

(ii) Nerve growth factor (118 AA) - influences development, maintenance and repair of nerve cells and thus would be significant for nerve restoration in surgery;

(iii) Erythropoietin - glycopeptide mainly responsible for blood cell development, may be useful for haemorrhages, burns, anaemia and other haemotologic conditions.

2. Immunoproteins

Immunoproteins are the class of proteins which are part of the immune system, e.g. antigens, interferons, cytokines and antibodies. Since polypeptides are so relevant to immunology, developments in genetic engineering will affect the entire field. Hence, genetic engineering is expected to play a major role in controlling immunological functions, particularly as it is the only known method of synthesizing many of the agents that comprise immunopharmacology.

(a) Antigens (Vaccines)

Genetic engineering could produce harmless vaccines to fight infectious diseases and scientists expect this areaa to benefit greatly from genetic engineering.

Immunity from live vaccines is greater than that from non-living antigens. This is thought to be because a living micro-organism can create more antigen over a longer period of time, i.e. provide a continuous "booster shot" effect. Thus, genetically engineered antigens are expected to provide a stronger and more sustained effect than the conventional vaccines. Additionally, the conventional vaccines, consisting of killed micro-organisms, produce a certain amount of side-effects.

Other vaccines which are expected to be produced via genetic engineering are those to combat influenza, polio, diphtheria, hepatitis and foot-and-mouth disease.

Genetic engineering could lead to other uses of antigens as well: vaccines against parasites(e.g. hookworm, or malaria), immunization regarding cancer treatment and counteracting abnormal antibodies against healthy tissues (e.g. multiple sclerosis).

(b) Interferons

Interferon is a protein which is produced by a variety of cells when infected with a virus. It inhibits viral reproduction and induces resistance in host cells. Additionally, interferon has been found to have at least 15 other biochemical effects partly involving other elements of the immune system.

Initial studies have shown interferon to be promising in the treatment of viral diseases, e.g. rabies, hepatitis, shingles and various herpes infections. Currently, several production methods are being investigated, namely extraction from white blood cells, tissue culture production and rDNA. rDNA is thought to be the key to mass production.

Since recent studies have shown interferon to be promising in cancer treatment, interferon production has received tremendous attention.

(c) Lymphokines and Cytokines

Lymphokines and cytokines are regulatory molecules studied in immunology (interferon is often considered to be a lymphokine that has been sufficiently characterised to be considered independent). Lymphokines, which are biologically active soluble factors produced by white blood cells, are throught to be directly involved in the immune response system. Cytokines, which have similar effects to lymphokines, include several compounds associated with the thymus gland.

Both lymphokines and cytokines are believed to be effective in treating cancer and genetic engineering is a useful tool for synthesizing them.

(d) Antibodies

Antibodies are proteins found mainly in the blood system. They are produced normally or in response to an antigen and characterised by a specific reactivity with its complementary antigen. Previously, all antibodies were produced from human or animal blood cells. However, now they can be produced using rDNA. This new high level of purity, not previously possible, produces antibodies which are more specific, and thus more effective. The application of antibodies in medicine includes diagnostic testing, improving acceptance of organs after transplants, and fighting certain types of cancer.

(e) Enzymes and Other Proteins

(i) Enzymes

Enzymes, the biochemical catalysts, play a small role in therapeutic medicine. Biologically, they are considered to be potent, versatile and diverse. Conventional methods of obtaining enzymes are either via extraction from human blood, urine, or organs, or production by micro-organisms. rDNA offers an efficient and more economic method of synthesising enzymes.

The main use of enzymes in medicine is to treat haemophilia. The most common agents are Factor VIII and Factor IX both of which are derived from human blood plasma. However, the risk of hepatitis associated with human plasma-derived products is very high. Thus, the need for high quality pure enzymes which could be derived from rDNA is strong.

Another enzyme, urokinase used for removing blood clots (which could lead to strokes, myocardial infarctions, etc.) is currently produced either from urine or tissue culture. Here too, rDNA could provide a more economical method of producing the enzyme.

(ii) Other Proteins

The structural proteins such as the collagens (the most abundant protein in the body), elastins, keratins, albumins, globulins and many others could be produced through genetic engineering.

However, their widespread use in medicines has to be established before warranting rDNA synthesis on an industrial scale. One notable exception, however, could be serum albumin which is a protein in blood plasma. Its main therapeutic use is to reverse the effect of shock. It is envisaged that the United States Department of Defence, for example, may find it valuable to have a ready source of human serum albumin rather than having to depend on blood donors.

(iii) Antibiotics

Antimicrobial agents for the treatment of infectious diseases have been the largest selling prescription pharmaceuticals in the world for the past three decades. Most of these agents are antibiotics - antimicrobials naturally produced by micro-organisms rather than by chemical synthesis or by isolation from higher organisms. However, one major antibiotic, chloramphenicol - originally produced by a micro-organism, is now synthesized by chemical methods. The field of antibiotics, in fact, provides most of the precedent for employing microbial fermentation to produce useful medical substances.

Antibiotics are complex, usually non-protein substances, which are generally the end-products of a series of biological steps. Not a single antibiotic has had its complete biosynthetic pathway elucidated. This is partly because there is no single gene that can be isolated to produce an antibiotic. However, mutations can be induced within the original micro-organism so that the level of production can be increased.

Other methods can also increase production and possibly create new antibiotics, for example, microbial mating. The technique of protoplast or cell fusion provides a convenient method for establishing a recombinant system in strains, species, and genera that lack an efficient natural means for mating. For example, as many as four strains of the antibiotic-producing bacterium Streptomyces have been fused together in a single step to yield recombinants that inherit genes from four parents. The technique is applicable to nearly all antibiotic producers. It will help combine the benefits developed in divergent lines by mutation and selection. The value of protoplast fusion, therefore, lies in potentially broadening the gene pool.

Recombinant DNA techniques are also being examined for their ability to improve strains. Many potentially useful antibiotics do not reach their commercial potential because the micro-organisms cannot be induced to produce sufficient quantities by traditional methods. The synthesis of certain antibiotics is controlled by plasmids, and it is believed that some plasmids may non-specifically enhance antibiotic production and excretion.

(iv) Non-protein pharmaceuticals

In both sales and quantity, over 80 per cent of the pharmaceuticals produced today are not made of protein. Instead, they consist of a variety of organic chemical entities. These drugs, except for antibiotics, are either extracted from some natural plant or animal source or are synthesized chemically.

Developments based on genetic techniques to increase the production and secretion of key enzymes could substantially improve the economics of some presently inefficient processes. Currently, assessments are being carried out by various companies to determine which of the many non-protein pharmaceuticals can be manufactured more readily or more economically by biological means.

(v) Impacts

It is worth emphasizing at this point that although genetic engineering provides an efficient and economic method for synthesis of pharmaceuticals, both the United States National Institutes of Health (NIH) and the FDA have to assess and approve each drug before it can be made commercially available.

By making a pharmaceutical available, genetic engineering can have two types of impact. Firstly, pharmaceuticals which already have medical promise will be available for testing (e.g. interferon). Secondly, other pharmacologically active substances which have no known use will be easily available for researchers to investigate their potential.

The ability of the new technology to increase and improve vaccine production through rDNA is indeed a boon to the people of the developing countries. Antibody-based diagnostic tests, developed through rDNA may include early warning signs for cancer.

Whether new pharmaceuticals are produced or new production methods for existing pharmaceuticals devised, future sources for the drugs may change. Currently, the sources are diverse plants, animal organs, tissue culture, cells and a range of raw materials, but with genetic engineering, the choice is narrower.

Given the above assumption, the immediate direct economic impact of using genetic engineering in the industry can be estimated in billions of dollars. While the indirect impact (sales for suppliers, savings due to decreased sick days, etc.) is estimated to be several times that value.

III. THE CHEMICAL INDUSTRY

A. General View

The organic chemicals initially used by humans to make useful materials, (e.g. cotton, linen, silk, leather, dyes, etc.) were all obtained from animals and plants and thus were renewable sources. At the beginning of the twentieth century petroleum, which was relatively cheap, began to be widely used as a raw material. However, due to the rising cost and rapidly decreasing sources of petroleum, the chemical industry is looking for alternatives. Most industrial analysts, therefore, expect a shift back to the natural renewable resources referred to as biomass. Genetic engineering will probably play an important role in enhancing the possibilities by allowing biomass and carbohydrates to be converted into chemicals. Biology is thus expected to have a dual function of providing both the raw materials and a production process for the chemical industry.

The chemical industry is one of the largest and most important in the world today. The main raw materials are petroleum, coal, minerals (phosphate, carbonate) and air (oxygen, nitrogen). About two thirds of the industry is devoted to inorganic chemicals (lime, salt, ammonia, chlorine, hydrogen chloride, carbon dioxide) while the remaining one third, which is the focal point for biotechnology produces organic chemicals (plastics, synthetic fibres, synthetic rubber, organic solvents).

A few industrial production processes utilise fermentation, e.g. the production of citric and lactic acids and various amino acids. Citric acid, which is one of the major industrial acidulants, is commercially produced by the mould Aspergillus niger. Lactic acid production is based on the bacterium species Lactobacillus. Most, if not all, of the amino acids have been the target for microbial production. The two important ones in the chemical industry produced by fermentation are glutamic acid (as a base for monosodium glutamate - a flavour enhancer) and lysine and L-lysine (as animal feed additives).

B. New Process Introduction

The introduction of biotechnology and genetic engineering to the chemical industry ought to be regarded not as the creation of a new industry but as the revival of an old one. The main advantages are envisaged as the use of renewable resources, less extreme conditions, use of single-step production processes and a reduction in pollution (e.g. a micro-organism could be constructed to directly convert cellulose in wood into ethanol).

1. Renewable Sources

During photosynthesis, plants convert carbon dioxide into carbohydrates. Part of the carbohydrates are, in turn, converted into the plant's energy requirements, while the rest are accumulated as starch, cellulose, lignins and other materials collectively termed as biomass. Now genetic engineering has the potential to alter the chemical industry's dependence from petroleum-based raw materials to biomass. However, since the cost of carbohydrates and other biological materials is also increasing the industry may be cautious at this stage

2. Physically Milder Conditions

Chemical reactions can be accelerated by increasing the temperatures and pressure or using a suitable catalyst. On the industrial scale, however, a catalyst, in addition to high temperatures and pressures, is necessary to produce most organic compounds. Enzymes can accelerate reactions without extreme physical conditions. Such reactions occur in dilute aqueous solutions, mild pH, ambient temperatures and atmospheric pressure.

3. One Step Production Method

The chemical synthesis of compounds, invariably a multi-step process, involves isolation and purification of each intermediate before it can be used. Furthermore, the chemicals used and the by-products of the reaction are often toxic and require special disposal. In biological systems, the conversion is a single step process (although several steps could occur within the micro-organism) minus the unnecessary labour of purification.

4. Reduced Pollution

Chemical reactions, both catalytic and non-catalytic, are not ordinarily limited to making the end-product exclusively. The formation of side-products and/or by-products and the incomplete conversion of starting material are common phenomena. When side-products and by-products are of no value or when unconverted raw materials cannot be economically recycled, waste disposal and pollution problems arise. A genetically engineered organism, however, can be product specific. Additionally, biological processes in general simplify product recovery. Furthermore, waste products, if created by biologically-based chemical processes, tend to be biodegradable as well as useful sources of nutrition.

The United States Environmental Protection Agency (EPA) estimates that chemical and allied industries, in the United States Government and industry together, will spend about $26 billion during the decade 1977-1986 to control air and water pollution. It has been speculated that if just five per cent of the industries used genetic engineering, the monetary saving on pollution could be $100 million per annum.

C. Industrial Chemicals That May Be Produced by Biological Technologies

1. Overview

Two questions are important when assessing the feasibility or desirability of producing various chemicals biologically. They are:

(a) which compounds can be produced biologically (even theoretically)?

(b) which compounds may be primarily dependent on genetic technology, given the costs and availability of raw materials?

Virtually all organic compounds can be produced biologically. Three variables affect the answer to the second question: the availability of an organism for the conversion, the cost of the raw material and the cost of the production process.

The constraints vary from compound to compound. However, although the role of genetics must be on a product-by-product basis, a few generalizations can be made. Overall, genetic engineering will have an impact on three processes:

(a) Aerobic fermentation - which produces enzymes, vitamins, pesticides, amino acids, nucleic acids and other speciality chemicals - is well established and should be allowed to grow. Production of both complex biochemicals (antibodies, growth factors and enzymes) and less complicated molecules (amino acids and nucleotides) is expected to increase;

(b) Anaerobic fermentation - which produces organic acids, methane and solvents - is an industrially expanding area. The main constraint on the production of other organic acids and solvents is a cheaper method to convert cellulose into fermentable sugars;

(c) Chemical modification of both aerobic and anaerobic fermentation products has promise. Biological technologies which operate at atmospheric pressure and ambient temperatures can replace the harsher physical conditions of the chemical technologies. This has already been attempted for ethylene glycol production which is awaiting patent approval.

2. Fertilizers, Polymers and Pesticides

(a) Fertilizers

The industrial production of nitrogenous fertilizers requires large amounts of gaseous ammonia (which in turn is made from petroleum by-products) and extremely high temperatures and pressures. The enzymatic conversion of atmospheric nitrogen to ammonia, nitrogen fixation, occurs in bacteria associated with the roots of leguminous plants. Apart from the enzyme's sensitivity to oxygen and the lack of understanding about its mechanism, the microbial production of ammonia is not yet considered economically viable. However, the genes for nitrogen fixation have been transferred into yeast thus opening up the possibility that agriculturally useful nitrogen can be made by fermentation.

(b) Polymers

A large part of the chemical industry is involved in polymer production which is based on petroleum and its by-products. Since polymers are built from monomers, which are chemically simple and available in relatively high yield from petroleum, their microbial production in the near future is not expected. However, the essential impact of biotechnology on polymer production is expected to be considerable. Most of the important constituents of cells are polymers (proteins, polysaccharides, polynucleotides, etc.). Since cells normally assemble polymers with high specificity, the ideal industrial process would have to imitate the biological process in every possible respect. A micro-organism would have to convert a raw material into a monomer, followed by polymerisation and then finally to form the end-product. A more likely application would be the development of new monomers for specialized applications. Since polymer chemistry is concerned with studying how their properties can be modified, it is conceivable that biotechnology could enable the modification of both function and form.

(c) Pesticides

The largest market in pesticides involves the chemical and microbial control of insects. Although microbial insecticides have been around for years, they comprise about five per cent of the market. However, recent successes in developing viruses and bacteria which produce disease in insects, and the negative publicity given to chemical insecticides, have encouraged the use of microbial insecticides.

Of the 15,000 known species of insects, only 200 are sufficiently harmful to warrant control or destruction. Fortunately, most of them are sensitive to certain micro-organisms which, if they are not toxic to humans, non-target animals and plants, could be commercially utilized as insecticides. Approximately 100 known species of bacteria are pathogenic to insects. But only three (*Bacillus popilliae*, *Bacillus thuringiensis*, and *Bacillus moritai*) have been developed into commercial insecticides.

Genetic engineering should make it possible to construct more potent bacterial insecticides by increasing the dosage of the genes that code for the synthesis of the toxins involved. It may also be possible to produce mixtures of genes capable of directing the synthesis of various toxins.

D. Constraints on Biological Production Techniques

The main obstructions to using biological production technology are associated with biomass; these include:

(a) competition with food needs for starch and sugar;

(b) cyclic availability;

(c) bio-degrability and associated storage problems;

(d) high moisture content for cellulosics and high collection and storage costs;

(e) mechanical processing for cellulosics;

(f) the heterogeneous native of cellulosics (mixtures of cellulose, hemicellulose and lignin);

(g) the need for disposal of the nonfermentable portions of the biomass.

For food-related biomass sources (sugar, corn, sorghum) there are few, if any, technological barriers for conversion to fermentable sugars.

However, if the fermentation of sugars is to be as profitable as their incorporation into food, subsidies will be required. For biomass sources (agricultural and municipal wastes, wood) technological barriers exist in collection, storage, pretreatment, fermentation and waste disposal. Furthermore, biomass has to be transformed into sugars by either chemical or enzymatic processes before fermentation can begin.

A second major problem is concerned with the purification stage. Most fermentation products are in dilute solutions and concentration is energy-intensive.

Although developments in genetics show tremendous promise for creating more versatile micro-organisms, they do not by themselves produce cheaper fuels or plastics. However, genetic engineering is expected to reduce the production costs in many steps.

E. Impacts

1. Overview

Cost of raw materials may become cheaper than the petroleum now used (especially if cellulose conversion technologies can be developed). The source of raw materials would be broader, especially since several types of biomass could be interchanged when necessary. Raw materials like organic wastes, could be processed both to produce products and reduce pollution. But, the impact on total imported petroleum will be low.

Impacts on the process include relatively cheaper production costs for selected compounds. Additionally, milder physical conditions can be used suggesting the process might be safer. Although chemical pollution may be lower alternate methods of disposal or new ones must be found for the micro-organism now used.

Impacts on products include both cheaper existing chemicals as well as completely new products. Furthermore, new uses for enzymes may expand and drive this sector of the industry.

2. Impacts on other Industries

Although genetic engineering will and can develop new techniques for synthesising many substances, the direct displacement of any present industry appears to be doubtful. Genetic engineering should be considered as another industrial tool. It is misleading to refer to "genetic engineering companies" as a new industry; the companies arose mainly to convert micro-organisms with little commercial use into micro-organisms with commercial potential.

Since genetic engineering is a relatively small-scale laboratory operation, genetic engineering companies will continue to offer services to companies where such expertise is lacking. Additionally, suppliers of genetic raw materials may decide to expand into the production of genetically engineered organisms. Finally, companies are beginning to examine their by-products or waste products as possible sources of conversion into useful products.

3. The Social Impacts of Local Industrial Activity

Despite the extensive media coverage of rDNA and associated genetic engineering research, there is little, if any, evidence that people who live near such companies are concerned about possible hazards. Companies, so far, have adhered to the NIH Guidelines.

4. Impacts on Manpower

Two types of impacts on workers can be expected:

(a) The creation of jobs that replace those held by others (e.g. a worker in chemical production may be replaced by one producing the same product biologically);

(b) Creation of new jobs.

Workers in three categories would be affected:

(a) Those involved in the fermentation production phase of the industry;

(b) Those involved in the R+D phase of the industry, particularly professionals;

(c) Those in support industries.

The number of workers involved in the production phase of biotechnology represents the major impact of genetic engineering. Estimates of the number of totally new jobs that would be created are speculative.

IV. THE FOOD PROCESSING INDUSTRY

A. General View

Genetics can be used in the food processing industry in two ways. Primarily to design micro-organisms that transform inedible biomass into food for human consumption or animal feed. Secondly to design organisms that aid in food processing, either by acting directly on the food itself or by providing materials that can be added to food.

Traditionally, micro-organisms were used to stabilize, flavour and modify properties of food. Recently, efforts were made to control microbial spoilage and to ensure that foods were free from micro-organisms that may be hazardous to public health. These are the two major ways in which microbiology has been useful.

B. Single-Cell Protein (SCP)

1. Introduction

Interest in augmenting the world's supply of protein has focused attention on microbial sources of protein as food for both animals and humans. Bacteria and/or yeast have been grown in large quantities to supply SCP for consumption. The protein can either be consumed directly as part of the cell or be processed into fibres. The idea of using SCP as animal feed or human food is not new; yeast has been used as food protein since 1900. Recently, however, there has been a sudden increase in research on SCP and in the construction of large-scale plants for its production, especially yeast production. Soyabean, too, is another quick source of protein and soyabean products are rapidly increasing in popularity. While significant research is directed at the genetic improvement of soyabeans, genetic techniques are also being investigated to increase the production of SCP. Thus, ironically, the same tool (genetic engineering) encourages competition between the two.

2. Genetic Engineering and SCP Production

Many substances are being considered as raw materials for conversion to SCP.

(a) Petroleum-based hydrocarbons - until recently the n-alkanes (petroleum by-products) were suitable raw materials for SCP production. At British Petroleum, mutants of micro-organisms with an increased protein content have been isolated. Mutants also have been found with other increased nutritive values, e.g. vitamin contents.

(b) Methane or methanol - relatively few genetic studies have been directed at investigating the genetic control of the microbial use of methane or methanol. However, Imperial Chemical Industries (ICI) has altered the genetic make-up of the bacterium so that the organisms can grow more readily on methanol. The increase in growth provides an increase in protein and has made production less expensive.

(c) Carbohydrates - many carbohydrate substrates have been investigated. Forests are the most abundant carbohydrate source (as cellulose). But the cellulose must be transformed by chemical or enzymatic pretreatment into glucose (the carbohydrate) before it can be used by micro-organisms. Many of the SCP processes that use cellulose employ organisms that produce the enzyme cellulase, and this degrades cellulose to glucose.

Recently, there have been some significant studies on the production of cellulose by micro-organisms. Some studies have also been done on creating fungal mutants that produce excess amounts of cellulose.

3. Commercial Production

It is estimated that 2 million tons of SCP are produced annually in the world. Most of this comes from cane and beet molasses, and about 500,000 tons from hydrolised wood wastes, corn trash and paper mill wastes.

It is possible to design integrated systems to couple food production (or other "product" production) with SCP production from wastes. For example, the waste sawdust from the timber industry could be a source of cellulose for micro-organism. The successful genetic engineering by ICI of a micro-organism to increase the usefulness of one raw material (methanol) is the beginning of similar attempts for other raw materials.

While SCP can be obtained from a wide variety of micro-organisms and raw materials - the nutritional value and safety of each micro-organism vary widely. So do the costs of competing protein sources in regional markets. Thus it is not possible to accurately predict the extent to which SCP will displace traditional protein products. Displacements will continue to occur on a case-by-case basis.

C. Genetics in Brewing, Baking and Winemaking

The micro-organism of the greatest significance in the above industry is yeast. Yeast was one of the first micro-organisms to be used in genetic research. However, in spite of studies in yeast genetics, its applications are few, for three reasons:

(a) Industries already have the desired strains (from trial and error);

(b) New genetic strains are not easily bred; they are incompatible for mating and their genetic characteristics are poorly understood;

(c) Many of the important characteristics of industrial microbes are complex - several genes are responsible for each.

1. Brewing

Due to the changing technologies in the brewing industry and increased sophistication in the molecular genetics of yeast, researchers have achieved new goals, for example, a low-carbohydrate beer for diabetics.

2. Baking

Yeast with new properties for the faster fermentation of dough are now being used. New strains, with improved biological activity, storage stability and yield permit improvements in the baking industry. Previously, most genetic application was in the formation of hybrid yeasts. The newer genetic approach, however, which uses cell fusion opens up possibilities of hybrids developed from strains of yeasts which carry useful genes but cannot mate normally.

3. Winemaking

Genetic research which was carried out with wine yeasts during the past 10 years has achieved the following:

(a) increased alcohol tolerance;

(b) improved sedimentation properties;

(c) improved performance.

Progress in developing strains of yeast with novel properties is hindered by lack of suitable approved systems for using recombinant DNA.

D. Microbial Polysaccharides

Polysaccharides are polymeric sugars which are used to alter or control the physical properties of foods e.g. as thickeners, gelling agents and agents to control ice crystal formation in frozen foods. Since polysaccharides are generally derived from plant sources microbial polysaccharides have had limited use. To be economically viable, a microbial polysaccharide has to be readily available, offer new properties and be considered "safe". To date very few have reached the commercial application level. The only one which is used extensively used commercially is Xanthum gum which is produced from Xanthomonas campestris.

So far, most of the work on polysaccharides has been on one particular strain, but there is growing evidence that they could also be produced from other strains. However, elucidation of the biochemical pathway for the synthesis of a particular microbial polysaccharide as well as an understanding of the systems that control microbial production are necessary before applying genetics.

E. Enzymes

1. Overview

Enzymes are produced for industrial, medical and laboratory use both by fermentation processes (using bacteria, moulds and yeasts) and by extraction from natural tissues. At present less than 50 microbial enzymes are of industrial importance but patents have been given for more than 1,000. This suggests that it may be easier to discover new enzymes than to find a profitable market for them. Most enzymes are used in the detergent industry and the food processing industry especially for processing starch.

2. Food Processing Industry

If biotechnology is applied to the fermentation processes, a larger number of enzymes will be made more available. Furthermore, genetic engineering can open up commercial possibilities in the food industry. Consider, for example, the enzyme pullulanase which degrades pullulan, a polysaccharide, to maltose or high-maltose syrups, which enhance the colour and brilliance of jams and jellies. Additionally, they also reduce the off-colour development produced by heat in sweets and prevent sandiness in ice creams by inhibiting sugar crystallisation. Maltose is also the least water-absorbent of the maltose sugars and despite being less sweet than glucose it has a more acceptable taste. Additionally, it is fermentable, nonviscous, easily soluble and does not readily crystallise.

Pullulanase can also break down another carbohydrate, amylopectin, to produce high amylose starches. These starches are used in industry as quick-setting, structurally stable gels, as binders for strong transparent films and as coatings. Their acetate derivatives are added to textile finishes, sizing adhesives and binders. In food, amylose starches thicken and give texture to sweets and sauces, reduce fat in fried foods and stabilize the protein, nutrients, colour and flavour in reconstituted foods e.g. meat analogues.

In view of the current shortages of petroleum-derived plastics and the need for a bio-degradable replacement, amylose's ability to form plastic-like wraps may provide its largest industrial market - but that market has not yet been developed.

If applications for the products made by pullulanase can be developed, genetic engineering can be used to insert this enzyme into industrially useful organisms and to increase its production. However, since the food processing industry can only use enzymes that are obtained from sources approved for food use, and since the chief source of pullulanese is a pathogenic bacterium, Klebsiella aerogenes, significant efforts have not been made to apply genetics to improve production or quality. Perhaps genetic engineering could transfer the pullulanase trait from Klebsiella aerogenes to a micro-organism which is approved for food use.

3. Sweeteners, Flavours and Fragrances

Biotechnology has had a marked impact on the sweetener industry. Due to the availability of the enzymes glucose, isomerase, invertase and amylase, the production of high fructose corn sweeteners (HFCS) has been profitable. For example, the Coca Cola Company uses five per cent fructose.

Although it is unlikely that sucrose will ever be made by micro-organisms, the microbial production of low calorie sweeteners is a distinct possibility. Three low calorie sugars, aspartame, monellin, and thaumatin have been studied.

F. General View

An industry-wide impact is not expected due to the following three reasons:

(a) The basic genetic knowledge of characteristics that could improve food has not been adequately developed;

(b) The food processing industry is cautious in its expenditures on R+D for important processes; generally, they allocate half as much as the more technically sophisticated industries;

(c) The products from the new microbial sources must satisfy the FDA safety regulations; it may be possible to reduce the amount of testing by transferring the gene into micro-organisms that already meet FDA standards.

However, it is expected that the application of genetic technologies will accelerate. The aim is to draw technically sophisticated companies into the business.

V. MINERAL LEACHING AND RECOVERY

Most genetically engineered micro-organisms are designed for contained facilities. However, some are examined for usefulness in the open environment for purposes like mineral leaching and recovery, oil recovery and pollution control. All three applications are characterised by:

(a) use of large volumes of micro-organisms;
(b) less control over the behaviour and fate of micro-organisms;
(c) possibility of ecological disruption;
(d) less basic R+D.

All micro-organisms interact with metals. Two interactions which are of potential economic and industrial interest are leaching metals from their ores and concentrating metals from wastes or dilute mixtures. The former would allow the extraction of metals from large quantities of low grade ores while the latter would provide a method for recycling precious metals and controlling pollution caused by toxic metals.

A. Microbial Leaching

When metals in ores are made soluble by bacterial action it is termed microbial or bacterial leaching. Historically, the process has been shown to be effective.

Leaching begins with the circulation of water through large quantities of ore. The bacteria, which are naturally associated with the rocks, then cause the metals to be leached. This is done by one of two general mechanisms - either the bacteria act directly on the ore to extract the metal or they produce substances (e.g. ferric iron and sulphuric acid) which then extract the metal. It has been shown that adding acid is not as efficient as using live bacteria. In fact, empirical evidence indicates that some of the bacteria involved in mineral leaching bind strongly to those minerals.

The application of the leaching process to uranium mining has aroused considerable interest due to the possibility of <u>in situ</u> mining. It has also been suggested that extending this practice to other mines would be environmentally beneficial due to the minimal disruption of land surfaces. Although the process is slower than the current technology, it is cheaper and simpler.

B. Applied Genetics in Strain Improvement

Thiobacillus ferrooxidans is the bacterium most studied for its leaching properties. Very little is known about the mechanism concerning the leaching ability in the bacteria. This is because very little information exists in two areas: the chemistry of interaction between the bacteria and the rock surface, and the genetic structure of the micro-organism.

Due to the lack of genetic and biochemical information about these bacteria, the application of genetic technologies to mineral leaching is still speculative. Progress is slow.

Even when scientific knowledge is gathered, two obstacles to the use of genetically-engineered micro-organisms will remain:

(a) The need to develop engineering systems on a large enough scale to exploit biological activities. A constant interchange between geneticists, geologists, chemists, engineers etc. must take place - i.e. each must understand the needs and problems of the other. The answer lies in forming an interdisciplinary group.

(b) This obstacle is environmental. Introducing large numbers of genetically engineered micro-organisms into the environment raises questions of ecological disruption, as well as liability, if damage occurs to the environment or human health.

C. Metal Recovery

The use of micro-organisms to recover metals from dilute solutions has two goals, namely to recover metals as part of a recycling process and to eliminate any metal that may be a pollutant. The process utilizes the ability of the micro-organisms to bind metals to their surfaces and then concentrate them internally.

Studies have shown that micro-organisms can be used to remove metals from industrial effluents. This is particularly useful for low concentrations (10 to 100 ppm) where non-biological methods are uneconomical.

The economic competitiveness of the biological methods have still to be proved; the genetic improvements, however, have been tried only recently. The cost of producing the micro-organisms has been a major contraint; if this can be reduced, the method might be useful.

Like other biological systems, genetic engineering may increase the efficiency of the extraction process. However, the capability to select cells with the genetic ability to accumulate large amounts of specific, desired metals will be a significant stride in designing a practical system.

VI. OIL RECOVERY

Oil production can be increased by the following three methods:

(a) accelerating exploration for new oil fields;

(b) mining oil shale and coal and converting them into liquids;

(c) developing new methods for recovering oil from existing reservoirs.

There are three methods of oil recovery - primary, secondary and tertiary. In primary methods, physical expansion is used to drive the oil out of the formation. In secondary methods, a fluid (water, natural gas) is injected into the reservoir to force the oil to the well. The tertiary method (also known as enhanced oil recovery (EOR)) is relatively new. It uses chemical and physical methods to increase the mobility of the oil - thus facilitating other forces to drive it out of the ground. It is here that genetic engineering could be used - e.g. a micro-organism could be used to help bring out the oil. The tertiary method is good for oil in sandstone and limestone reservoirs as well as for sands and oil shale.

A. Enhanced Oil Recovery

There are four EOR processes - all aimed at dislodging crude oil from its natural (geological) setting.

1. Thermal

The oil reservoir is heated which leads to a decrease in the viscosity of the oil. Using the pressure of the air that is introduced, combustion occurs which in turn forces the petroleum to the producing well. Thermal processes cannot be improved using genetic technologies.

2. Miscible Processes

This process injects chemicals which stand with the crude oil to form mixtures that flow more readily. The chemicals used are alcohols, carbon dioxide, petroleum hydrocarbons (e.g. propane, butane) and petroleum gases. A fluid (usually water) is used to push the slug of these chemicals through the reservoir to mix with the crude oil and move to the surface.

3. Alkaline Flooding, Polymer Flooding and Combined Surfactant/Polymer Flooding

(a) Alkaline Flooding - sodium hydroxide, sodium carbonate or other alkaline materials are used to enhance the oil flow. Neither natural nor genetically engineered micro-organisms are considered useful here.

(b) Polymer Flooding - this is a recent and successful method which depends on the ability of polymers to increase the viscosity of water. Instead of altering the characteristics of crude oil, it aims to make the injected water more capable of displacing it.

(c) Combined - here a surfactant (detergent-like material) is used to loosen the oil from the surrounding rocks, while the water that contains a polymer (to increase its viscosity) is used to drive the oil from the reservoir.

4. Other EOR Methods

This includes many novel possibilities e.g. the injection of live micro-organisms into a reservoir - these may produce any of the chemicals, from surfactants and polymers to carbon dioxide, used in the miscible and flooding processes.

B. Microbial Production of Chemicals used in EOR

EOR methods which use chemicals tend to be costly due to the cost of chemicals. However, potentially useful polymers were found in the early 1960s and have been used since for oil recovery e.g. polyacrylamide and xanthan gum both of which can increase the viscosity of water in concentrations as low as one part per thousand. Xanthan gum, which can be made by micro-organisms, has good viscous properties but it is expensive to make. Furthermore, if it is not exceptionally pure, it can plug reservoir pores. The fluid has to be filtered carefully to remove bacterial debris before it is injected.

However, it is possible to genetically engineer a micro-organism which can overcome many difficulties; e.g. polysaccharides (polymeric sugars), with improved properties, could be obtained by microbial fermentation and used effectively.

Biological processes have disadvantages too, mainly in the costs of appropriate raw materials and the need for large quantities of solvents. Recent efforts to find cheaper raw materials e.g. sugar beet pulp and starch show promise. It is possible to overcome the problem of precipitating and concentrating the polymers by producing them in situ (on the site). Micro-organisms can also produce butyl and propyl alcohols that can be used as co-surfactants in EOR.

The lack of technical and economic data together with insufficient field experiments makes the situation uncertain. Each oil field has its own set of conditions and laboratory tests are insufficient to determine field conditions.

C. Use of Micro-organisms In Situ

If micro-organisms could be injected directly into wells then the chemicals could be produced in situ (by the micro-organisms). However, geophysical and geochemical conditions in the reservoirs seldom favour the growth of micro-organisms. The problems are: high temperature, presence of sulphur and sodium chloride, low oxygen and water, extremes of pH and engineering hurdles.

The micro-organisms must be fed and the micro-environment must be carefully adjusted to their needs at thousands of feet. However, information from geomicrobiology suggests that this approach is worth pursuing , e.g. injection of Bacillus or Clostridium species together with a water suspended mixture of fermentable raw materials (cattle feed molasses and mineral nutrients) has produced plenty of carbon dioxide, methane, and some nitrogen in the reservoirs. The carbon dioxide made the crude less viscious and the other gases aided in redressing the reservoir pressure. Furthermore, large amounts of organic acids formed additional carbon dioxide through reactions with carbonate minerals. The production of microbial surfactants further aided this process.

Although it was formally believed that reservoir pressure hindered the growth of micro-organisms, recent data shows this is not so.

However, the micro-organism must be selected for increased salt and pH tolerance.

D. EOR and Genetic Engineering

The current research approach is a two phase process. The initial one is to find a micro-organism which can function in an oil reservoir environment with as many of the necessary characteristics as possible. The subsequent one is to alter the micro-organism genetically to enhance its overall capacity.

The genetic engineering of micro-organisms to produce chemicals which can be used in EOR has been successful, whereas the genetic engineering of micro-organisms to be used in situ has been less successful

E. Constraints to Applying Genetic Engineering Technology in EOR

The genetic data base for micro-organisms that produce useful polysaccharides is weak and thus theoretical studies cannot be done just yet.

The biochemical data base for characteristics of both the micro-organisms and their products is also lacking. There is potential, however, for chemical reactions carried out by microbes - this has to be further investigated. Furthermore, a classification and characterisation system for the micro-organisms must be devised.

The physical data base for oil reservoirs is limited due to the uniqueness of each reservoir. No universal micro-organism or method of oil recovery will be found. This is further complicated by the lack of sufficient physical, chemical and biological information about reservoirs - and without this it is not possible to rationalise a constructive genetic scheme for strains. The conditions have to be known.

There are three institutional objectives. Primarily since most of the research results are confidential, the number of available publications is limited.

Secondly, neither the private nor public sector is enthusiastic about the potential use of micro-organisms in EOR. The biological approach has only recently been considered. Thirdly, any efforts to use micro-organisms must be multidisciplinary. Geologists, microbiologists, chemists and engineers must interact.

The environmental and legal concerns have also restricted progress. Since microbial EOR methods require plenty of fresh water, they could compete with municipal and agricultural uses. The immediate environmental and legal concerns stem from the potential risk associated by releasing micro-organisms into the environment. When the organisms naturally cause disease or environmental disruption, the use is limited. When they do not, the risk is always there. Caution has to be exercised at all times.

F. Genetic Engineering for Other Aspects of Oil Recovery and Treatment

Two other aspects of microbial physiology are: the microbial production of oil muds or drill lubricants and the post recovery microbial treatment of oil. Drilling muds are suspensions of clay and other materials. These lubricate the drill as well as counterbalance the upward pressure of the oil. Microbially produced polysaccharides are being developed for this purpose.

The post recovery microbial treatment of oil concerns the ability of micro-organisms to remove undesirable constituents from the crude oil. Recently, three microbial systems have been developed to help remove aromatic sulphur-containing materials - a major impurity.

G. General View of Genetic Engineering in Mining and Oil Recovery

The main thrust is in developing genetically engineered micro-organisms in either mining or oil recovery. Both require land and materials such as fluids and micro-organisms in large quantities. Laboratory test results cannot be automatically extrapolated to industrial applications. Furthermore, the variables in the natural environment cannot be envisaged. However, due to the potential value of the products in these areas research and development will continue.

VII. POLLUTION CONTROL

Micro-organisms have been used for years to degrade and detoxify human sewage. Now, micro-organisms are used to tackle pollution problems caused by industrial toxic wastes.

Pollution problems have been categorised into two areas - those present for a long time in the biosphere (e.g. hydrocarbons found in the petroleum industry and in human and animal wastes) and those which are the result of human inventiveness (e.g. pesticides). Chemicals of both sorts (due to various reasons) often appear in places where they are hazardous to humans or the environment.

Microbes can control pollution in two ways: either by enhancing the growth and activity of microbes already present at or near the site of pollution, or by adding more and/or new microbes to the site. Genetic engineering cannot aid the former. However, genetic engineering could make a significant contribution to the latter.

Some companies have already marketed microbes which could be added to the site. In addition, certain microbes are geared for specific problems, e.g. oil, sewage, etc.

The cities are cautious about adding bacteria to large municipal sewarage systems, but the view that bacteria may be useful in smaller installations and for specific problems has gained support.

The resistance to genetically engineered bacteria is not universal. Many industrial wastes are oxidised to non-toxic chemicals by biological treatment in aerated lagoons. The process depends on the presence of microbes in lagoons - the microbes that grow best on the waste eventually dominate the microbial population of the lagoon. Three companies now sell bacteria which they claim are more efficient than the indigenous strains found in the lagoon.

There exists, however, a disagreement regarding the value of adding microbes to decontaminate soils or waters. One view contends that serious spills often sterilise soils and adding microbes is necessary for any biodegradation, while the other argues that encouraging indigenous microbes is more likely to succeed as they are accustomed to the spill environment.

Thus, although genetics has not been much applied to pollution control, the potential is strong. The constraints are:-

(a) health, economic and environmental damage;

(b) added organisms are unlikely to be a significant improvement;

(c) selling microbes rather than products or processes is unlikely to be profitable;

The factors which have discouraged development are:-

(a) no convincing evidence that microbes could remove or degrade an intractable pollutant;

(b) the research required to produce marked improvements is inhibited.

In order to overcome this inhibition, governments need to support the research, buy the microbes and to provide for protection against liability suits. Such a stand would help protect health and the environment from the toxic effects of pollutants.

ANNEX

TIME HORIZONS FOR COMMERCIALIZATION OF GENETICALLY ENGINEERED STRAINS

Five years	Current market value ($ million)
Amino acids (arginine, aspartate, cysteine, glutamate, lysine, phenylalanine, threonine, tryptophan)	1 409
Enzymes (α-amylase, amyloglucosidase, asparaginase, 1/ *Bacillus* protease, glucose isomerase, glucose oxidase, papain, pepsin, rennin, tyrosine, 1/ urokinase)	218
Peptide hormones (adrenocorticotropic hormone (ACTH), bovine growth hormone, 2/ endorphins, 1/ enkephalins, 1/ glucagon 1/, human growth hormone, insulin, vasopressin 1/)	264
Viral antigens (avian leukemia, avian myeloblastosis, Epstein-Barr, hepatitis, herpes, hoof and mouth, Rous sarcoma, rubella, varicella)	n.a.
Short peptides, nucleotides and miscellaneous proteins (aspartame, glycine-histidine-lysine, interferon, human serum albumin)	304
Pesticides (microbial)	25
Aliphatics (ethylene glycol, ethylene oxide, glycerol, itaconic acid)	1 225

1/ Market information not available

2/ No market value at present

	Current market value ($ million)
Aromatics (aspirin, p-acetaminophenol)	99
Total	3 544

Ten years

Amino acids (methionine)	294
Vitamins (nicotinic acid, riboflavin, vitamin B_{12}, vitamin C, vitamin D)	561
Enzymes (ethanol dehydrogenase, hydrogenase)	n.a.
Corticoids (cortisone prednisone, predisolone aldosterone)	306
Androgens (testosterone)	11
Estrogens (estradiol)	60
Peptide hormones (ovine growth hormone, porcine growth hormone)	n.a.
Viral antigens (influenza)	n.a.
Short peptides, nucleotides and miscellaneous proteins (5^1-IMP, 5^1-GMP, monoclonal antibodies)	72
Antibiotics (penicillins, tetracyclines, cephalosporins, erythromycins)	2 560
Pesticides (aromatics)	75

	Current market value ($ million)
Aliphatics (acetic acid, acrylic acid, adipic acid, ethanolamine, isobutylene, methane, pentaerythritol, propionic acid, propylene glycol, sorbitol)	12 904
Aromatics (aniline, benzoic acid, cresols, phenol)	663
Total	17 506

Fifteen years

Vitamins (vitamin E)	106
Viral antigens (reoviruses)	n.a.
Gene preparations (sickle cell anaemia)	n.a.
Aromatics (pthalic anhydride)	259
Inorganics (ammonia, hydrogen)	2 631
Total	3 046

Twenty years

Gene preparations (hemophilias, thallasemias)	n.a.
Aliphatics (Bis (2-ethylhexyl) adipate), critronellal, citronellol, geraniol, linalool, linalyl acetate, nerol, α-terpineol, α-terpinyl acetate)	57

	Current market value ($ million)
Aromatics (cinnamaldehyde, diisodecyl phthalate, diocytl phthalate)	231
Total	288

	Current market value ($ million)
Five years	3 544
Ten years	17 506
Fifteen years	3 046
Twenty years	288
Total	$24 384

Note: Except for aromatics and aliphatics, all market data represent worldwide estimates. Market data for aromatics and aliphatics are restricted to the United States.

MOD 13

A RE-APPRAISAL OF THE JOINT VENTURE AND TECHNOLOGY AS A MEANS TO PETROCHEMICALS PROMOTION

by
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Introduction

State control of foreign-owned oil extraction operations in the developing countries is an irreversible historical process which is now more or less complete. Meanwhile the development and increasing geographical deployment of joint ventures in the newly developed industries in the LDCs seems to have gone hand-in-hand with the phasing-out of the concession system and other legal forms of foreign property in the mining sector. Iran was the first major oil producer to take over its oil industry, and it was also the first such country to apply the joint-venture strategy to promote petrochemicals manufacture. In the 1972-73 period, certain well-known Arab authors such as Sheikh Abdallah Al-Tariqi and Dr. Nicolas Sarkis disagreed with the view that the Saudi Arabian Oil Minister Sheikh Ahmed Zaki Al-Yamani was then advocating, i.e. that participation in the oil industry should be strategic issue for the Gulf countries. That is not our position, since we take the view that legal and formal retreat from the oil extraction sector is an irreversible process being undertaken by the multinational oil companies in countries such as Iran and other oil exporting countries, be they Arab or not; this process was historically connected with a fresh expansion of chemical refining and petrochemical processing on the basis of joint ventures[1]. Indeed, what happened in West Asia and Arab North Africa, for example, was that a process which started in Latin America was transferred to Iran and then increasingly to Arab oil exporting countries. The striking fact is that this process is currently under way.

From a formal point of view, many people (to begin with, executives of oil majors and petrochemical corporations) consider the joint venture as the least risky of petrochemical ventures for a so-called developing country. While most of the decision-makers in the OPEC and non-oil producing countries also share the same conviction that various local constraints act on petrochemical ventures of their own and make the risks prohibitive, few people are very doubtful of the social or commercial profitability of joint ventures.

One can certainly level criticism at the use of sales of technology and know-how as a privileged channel for the international transfer of value, and the oil-producers were the first to suffer widely from this. From this point of view, the joint-venture can be seen as a means for the developed market economies to siphon off wealth created by and in the non-integrated industries newly set up in the developing countries.However, the sale of over-priced equipment and technology and what could be called technological import substitution, can be no less disadvantageous to the developing countries than the channels and mechanism of the joint-venture.

Source: OPEC REVIEW, Vol. II, No. 2
Vienna, April 1978

This may explain two facts: (a) why many foreign companies are prepared to adapt to projects financed by local or state capital and (b) how a developing country can shift its position from one of opposition to the joint-venture to one of active promotion. It also explains why some multinational companies are quite prepared to sell off their equity share to the local associate – in most cases the state – in a developing country. Japanese firms, in particular, have followed this pattern in South East Asia.

In the analysis we shall examine the issues related to the role played by the joint-venture in the development of the petrochemical industry in the developing world, and consider the implications for OPEC Countries looking to strengthen their operations in this sector. Firstly, however, we will briefly consider an important type of joint-venture which for obvious reasons, is outside the scope of our study.

Joint-Ventures Between Oil Majors And Petrochemical Companies

The interpenetration of oil and petrochemical companies is a current fact of life. In the case of oil majors and large petrochemical companies, particularly in the United States, a joint extension of production capacity is increasingly being achieved in the chemicals refining sector, via the joint-venture. In some cases, a major petrochemical group may start up its own independent crude processing plant, and will then seek a partner and tranform the operation into a joint-venture which can supply part of the crude and take a part of the production. In 1977, for example, Dow Chemical, a leading US petrochemical company negotiated the sale of 50% of its interests in its crude oil processing plant under construction at Freeport in Texas. The asking price was said to be some $250 million. The plant will process some 180,000 barrels per day of crude, half of which will be supplied by the partner, who will get in return half of the production. The plant, which is worth significantly more on-stream than its original cost to the company, will enable Dow to shut down some facilities by 1980, according to its Vice-president, David Rooke[2].

This tactic of postponed joint-sharing adopted by a major petrochemical company to develop its vertical integration upstream holds three major advantages for the company:

1. It obtains and partly secures crude oil supplies for the new plant through the partner.

2. It reduces the marketing risks of the plant's production by transferring 50% of that risk to the partner.

3. By selling a 50% equity at a higher price than the original cost to the firm of its construction, it improves the company's financial position.

One can argue about the "balance" of joint-ventures of this type in the light of the two associates' respective contributions and advantages, but this would lead us on to a case study of the interpenetration of the oil and chemical industries.

1. A Reappraisal of Joint-Ventures

Traditionally, a joint-venture operation is sought to constitute a specific pool of functional factors of production, which, when combined, lead to some form of manufacture (or marketing). These factors are basically the following: funds for investment, raw materials, technology and market outlets. On the basis of combinations of these factors, the associates involved carry out a particular project. While these partners judge their joint-venture indispensable, balanced and mutually profitable, they will regard it as permanent[3].

Many decision-makers may perceive a joint-venture as a relationship that can be balanced in a way to be mutually beneficial and durable. The tendency of a joint-venture to dislocate is, in their opinion, neither inherent nor inevitable. They assert that all that is needed, is that when two or several partners get involved in a joint venture, they need only regulate it and adjust its mechanism periodically, thereby eliminating any eventual danger of imbalance and the folding-up of the venture[4].

To return to the main point of our analysis, however, we are primarily concerned with the type of joint-venture seen in the manufacturing sector, which brings together entrepreneurs from a developed country and state-controlled or even private interests in a developing country[5]. In such a case, the latter partner having supplied the raw materials, most of the investment and probably outlets, sooner or later comes to the conclusion that his deal with the partner is inequitable, or unprofitable or not even indispensable. At the same time the industrialised partner, fearing future nationalisation of his interests, does all he can to extract the maximum. Indeed, this proves to be the objective of a partner disposing of technology, know-how, marketing techniques and outlets, not to mention the factor of political lobbying.

In fact, joint-ventures of this type reflect from the outset a power relationship due to the hierarchy existing at the level of natural, compound and other factors of production. In other words, the dominant partner, the one who owns at any given moment the most indispensable and profitable factors of production, always ends in turning the joint-venture to his advantage. Inevitably that joint-venture will be dislocated.

But this is the result of a lengthy, historical process. It is only when industrialization within the developing country becomes far advanced and the state or local entrepreneurs feel they are in a position of strength and confidence that the power relationship of a joint-venture becomes balanced. We have seen this in the case of Brazil, for example. In any case, determining factors will be political willingness and the retention of economic sovereignty.

Since industrial processes in the Gulf area are still in their infancy, and the economic structures of most of its Kingdoms and Emirates are still vulnerable, joint-ventures have been increasingly established since the sharp rise in crude oil prices after 1973. Moreover, despite the fact that the economic recession, in generating over-capacities on the market, has a contradictory effect[6] on the relocation or planning of new industrial projects, US and other oil companies, American and European petrochemical groups and Japanese corporations are setting up joint-ventures with local interests in the Gulf. The need to secure access, especially at low cost, to Middle East raw materials* and, in several cases, to available capital and local tax and price advantages, is behind this move towards the Gulf. Also playing a determining role is the geographical location of this area, which is turned towards major potential markets in Asia and East Africa as well as to existing markets in Western Europe. These are the markets at which the US, European and Japanese corporations aim.

2. National and Multinational Integrated Corporations and Industrial Relocation

Multinationals may push one another into redeploying and transferring projects to developing countries. On the subject of oligopolistic matching behaviour, Knickerbocker demonstrated that in highly concentrated industries, US companies typically matched foreign investment moves by rivals as part of their strategy of risk minimisation. If one oligopolist established a foreign manufacturing operation, others did the same, in order to be at least no worse off than the leader[7].

In contrast to the generally held view, it is not the biggest and most multinational corporation that forces the pace of world-scale location of manufacturing, but rather small or medium-sized companies with a national or very limited multinational vocation, and which are only partially vertically-integrated. Looking at manufacturing as a multi-stage and integrated production process, the multinational corporation is in possession of too many advantages: access to, and control of, raw materials, long technological and manufacturing experience, large capacity and wide financial autonomy. This in turn provides huge investment facilities, distribution channels, marketing skills and opportunities for political lobbying. Considering the specific case of the petrochemical industry, which is a typical example of multi-stage integrated manufacture, multinational corporations may be tempted or even obliged to shift certain new plant projects. It will then split them, within the limits of technological and market constraints, into several projects covering different production stages in different countries.

2.1. Since chemical refining, the processing of basics and intermediates are assessed as capital-intensive, the multinational corporation would carry out these production sequences in countries which, for historical reasons, are the developing ones, rich in raw materials and capital, and with small populations. Such projects are by necessity export-oriented. This fact is borne out by recent experiences in the oil exporting countries.

* *By Middle East raw materials, we mean oil-associated gas reserves.*

2.2. Since downstream operations i.e. final-product manufacturing, are largely labour-intensive, appealing directly to consumer markets, the multinational would carry out this production in highly-populated developed countries where consumption is high. Projects of this kind were originally set up of necessity in developed countries, and then subsequently, in response to market needs, in a number of developing countries of Latin America and Asia. In any case it is not likely that a multinational company would set up a fully-integrated petrochemical manufacturing process in a well-populated developing country, because that country could orient such a complex towards the home market, thereby severing it from the multinational conglomerate's world scale network.

2.3. It goes without saying that joint-ventures established with such a multinational in either of the two partial-manufacturing cases, can be looked upon as a power relationship, disadvantageous to the developing partner. Export-orientation is aimed more at strengthening the multinational's world-wide manufacturing and/or marketing strategy than helping the weaker partner. This in turn can add to the historical disintegration of the developing region to which the host country belongs, with the latter being drawn into the multinational's developed home nation or region.

3. *Methods for Appraising the Transfer and Relocation of Integrated Plant*

In countries such as Iran, Saudi Arabia and Kuwait, multinational companies have planned, or are already implementing, full-integrated petrochemical projects (mostly export-oriented). We can appraise these projects in the following terms:

3.1. Projects of this kind are inherent to a market-type economy (i.e. export-oriented and adding to the Western-controlled international petrochemical industry and Western market economies as a whole). They are in line with that dynamic known as the product cycle and the resultant manufactured products, such as high and low-density polyethylenes, are already "common" products which very quickly become "mature". This means that, with technological improvements, they will hardly be competitive on world markets before the late 1980s. With technological innovation, if not revolution, likely by the 1990s, these products will thus be out of date. How can a multinational oil corporation offer more sophisticated and more innovative products, when it is not itself considerably involved in petrochemicals? Petrochemical companies are only too aware of the need for them to maintain a substantial and dynamic differential between their own know-how and processes and what they are prepared to concede and transfer as techniques and products to a developing country.

3.2. For some time now, the quantitative distribution of equity capital among associated shareholders has been accepted and applied as a criterion for appraising the balance in a joint-venture. When the equity is equally shared between foreign interests and local capital (whether state-owned or private), then the joint-venture is a balanced one. If foreign interests control the majority of the shares, the joint-venture is more profitable for those interests than it is for the host country. In the opposite case, many advocate the control by the developing host country of the joint-venture operation so that these larger profits are kept in check. We, however, take a different view from what is a rather simplistic analysis. Because of both the unequal value of the different factors of production and their dynamics, and the changing patterns of industrial processes in general – not only those of the petrochemical industry – a different approach is indispensable if one wishes to appraise this major shareholding aspect of the joint-venture.

3.2.1. As regards chemical refining, basic processing and *a fortiori*, fully-integrated manufacturing, multinational companies seek to put the larger part of the financial burden of investment firmly on the shoulders of the oil-rich developing countries.

The National Petrochemical Company (NPC) of Iran negotiated in December 1976, London loans totalling $360 million. This was raised as two separate borrowings of $310 million and $50 million, from Chase Manhattan and Kuhn Loeb respectively.

The larger sum, guaranteed by the Government of Iran, will be used to finance the Iran-Japan Petrochemical joint-venture at Bandar-Shahpur and a fertilizer project at Shiraz. The $50 million loan, without government guarantee, is destined for Shahpur Chemical Co., a wholly-owned subsidiary of the Iranian NPC. Of the $310 million, $280 million is to be used to finance the Iranian share in the Iran-Japan project (NPC and a group of Japanese multinationals led by Mitsui and Co.), costing a total of $1.833 billion, which centres on a 300,000 ton/year ethylene plant and other major derivatives units. Japan is providing $833.6 million, Iran $366.4 million and $333 million will be raised from equity capital.

Japanese Mitsui and Co. gives a total cost of $1.5 billion for the Shahpur complex, and a figure of 300 people to be employed in the project, once on stream. This gives an average rate of $500,000 investment per worker, the most significant illustration of over- capitalization of projects in the Gulf and North Africa. The remaining $30 million provided by Chase Manhattan is to be used by the Iran Fertilizer Co. to expand four product lines at Shiraz.

The $50 million loan will be used for general expansion of Shahpur Chemical's production facilities, to finance the 1,000 ton/day ammonia and 1,500 ton/day urea plants under construction at Bandar Shahpur. Both loans will be at an interest rate of 7/8 per cent above the London Interbank rate. The larger is repayable over eight years, while the Kuhn Loeb loan is for a period of seven years.

Bearing in mind the fact that Qatar was obliged to raise $230 million to finance its future equity in the QAPCO petrochemical complex projected in the Emirate[8], let us try to test how oil and petrochemical corporations overcome financial constraints and conclude joint-ventures with developing countries.

3.2.2. In the case of petrochemical corporations, financing new investments is as much a structural constraint as an urgent and long-term need to extend geographically and develop vertically both their manufacturing processes and markets.

For more than 20 years, chemical companies have been shifting away from carbon to naphtha (and natural gas) feedstocks. By depriving Middle East oil-exporting countries of their rightful rent for their oil, the oil company cartel - only formally dissolved after the Second World War – was able to apply artificially low selling prices, thereby making available cheap refinery products as feedstocks to Western and Japanese petrochemical industries. In this way, petrochemical companies were able to share rent and profits from crude oil.

The conversion from coal-based chemicals manufacture to petrochemicals gave a dramatic impetus to the developed countries' production and consumption. Thanks to the new low-priced feedstock and the highly profitable oligopolistic characteristics of the market, the petrochemical industry was able to finance itself from its own resources to the tune of a figure approaching three quarters of its past investment. At the macro-economic level, the industrialised home countries of those companies allocated to petrochemicals promotion, on average, between 0.6 and 1.6% of their gross fixed capital formation and what was equivalent to 0.15 to 0.2% of their Gross Domestic Product. The world range was in fact larger, varying from 0.15 to 0.4% of GDP.

For short and longer-term petrochemical investments, BEICIP, the French state-controlled engineering consultant, estimates, on the basis of assessed planned projects, short-term petrochemical investment over the period 1977-1980 at 0.16% of GDP, and for the years 1981-1985, 0.17% of GDP. Rates of petrochemical investment as a share of total gross fixed capital formation forecast for the next nine years are likely to be similar in relative terms to those assessed over the years 1960-1974. Nevertheless, the international petrochemical industry will have to raise its investments substantially – considered in absolute terms – between now and 1985. Due to dramatic, though insufficient increases in crude oil prices, not much higher in real terms than those in operation in 1974, feeds and energy costs have multiplied (in the case of naphtha, for example, by some 300%) . Given also the prevailing economic recession, it is not difficult to see why profits in the petrochemical industry have declined in recent years. With the increasingly urgent need to reduce raw material requirements and costs by changing fundamentally the patterns of technology and manufacturing, it can be assumed that the petrochemical industry has to a large extent lost its comfortable financial autonomy and the advantages of self-investment.

Short and long-term indebtedness of the world's top ten chemical companies was already significant by the autumn of 1976, as the table below shows:

THE WORLD'S TOP 10 CHEMICAL COMPANIES

Company	Sales in bl of Dollars	Net profit ml of dollars	Debt Long-term Billion of dollars	Debt Short-term Billion of dollars	Number of employees	Aftertax profit per employee dollars	Aftertax profit margin Percent
*Hoechst	10.0	246	3.6	2.8	182,980	1,344	2.5
BASF	8.9	257	2.0	2.0	112,686	2,284	2.9
Bayer	8.9	193	3.2	2.7	171,200	1,127	2.5
Du Pont	8.4	459	1.3	0.259	132,737	3,453	5.5
ICI	7.0	417	1.8	0.308	192,000	2,169	5.9
Union Carbide	6.3	441	1.6	0.273	113,120	3,902	6.9
Dow Chemical	5.6	613	1.9	0.494	53,000	11,566	10.8
Montedison	5.5	(197)	2.1	1.4	144,545	–	–
Rhône-Poulenc	4.4	(73)	1.2	2.0	113,000	–	–
Monsanto	4.3	366	0.915	0.117	61,900	6,000	8.6

Fiscal 1976

* *including 100% of joint ventures*

Reference: Date supplied by Investor Management Sciences Inc.: BUSINESS WEEK, July 25, 1977, page 78.

The highest indebtedness ratios were those of the first three companies – Hoechst, BASF and Bayer – all West German; the eighth, Italian company Montedison; the fourth, British ICI; and the ninth, French company Rhone Poulenc – in other words all West European corporations. By contrast, American companies such as Du Pont, Union Carbide and Monsanto had the lowest ratios[9]. If we compare long-term and short-term debt, ratios for the first range appear systematically higher than those for the second, except in the case of the French group, Rhone Poulenc. Long-term indebtedness ranges between $3.6 billion for the German company, Hoechst, and $0.915 billion for the US company, Monsanto. Short-term indebtedness ranges between $2.8 billion in the case of Hoechst to $0.117 billion for Monsanto. In any event, as a result of losing their major advantage of low-priced gas feedstock and converting to naphtha (because of the growing US oil shortage and increased imports), thereby joining their West European and Japanese competitors, US companies predict steady rises in their indebtedness ratios. By becoming increasingly less competitive in export markets, those American companies will be more and more inclined to establish joint-ventures at home and abroad.

It is not difficult to demonstrate how state intervention in Western Europe in general, but especially in France, Italy and West Germany, helps on a local or national basis to secure company finances and improve their prospects. In France, for example, state intervention to marry public and private domestic oil interests has persuaded such companies to move into petrochemicals on the basis of structural subsidising. Take, for example, the merger between state-controlled Elf-Aquitaine and the private/state company CFP, to form ATO-Chimie, which later absorbed or took control of private, and specifically French, chemical companies.

The French company, Rousselot, the world's number one gelatine producer, almost came under the control of British Petroleum, until the French authorities intervened and put pressure on the company to become a 66% subsidiary of the French state-controlled ATO-Chimie (itself a joint subsidiary shared by the state-controlled Elf-Aquitaine and Total). The French government also intervened to prevent private fertiliser company, Gardinier from being bought out by a Dutch company under the partial control of the Anglo-Dutch multinational, Shell. Instead it gave the French chemical and textile concern, Rhone Poulenc, the opportunity to acquire Gardinier[10].

The French are pushing ahead with their current activities to attain the first up-stream phase, further chemical refining and, also direct feedstock supplies(basically oil, but also associated gas), in order to gain access to, and drain the maximum rent from, oil and gas. At the same time they are retreating from loss sectors, such as synthetic fibres, and closing certain fibre and plastics plant[11]. Thus the reshaping of the patterns of manufacture and production is stimulated by access to and control of the feedstock, and enhanced by the need to extend existing markets and mobilise those which are latent or potential, especially in the developing countries.

Under these circumstances, heavy investment for the petrochemical companies is as much a method of escaping their present structual crisis, as a means to further develop their multinational dimension and vertical integration, whereby they quite naturally seek developing countries which are rich in oil and gas resources and capital, as well as those offering cheap labour and potentially large markets. Since crude oil prices increased naphtha prices by about 300%, petrochemical companies have expanded chemical refining joint-ventures with the major oil companies, as well as processing and integrated petrochemical complexes with those Middle East countries with plentiful oil and gas supplies. They have extended their joint-ventures in Iran[12] and inaugurated a similar policy in Saudi Arabia[13]. For these companies such a policy has the double advantage of giving them direct access to and an opportunity to co-exploit, Middle East oil, or more particularly associated gas supplies, and also of adding to their financial reserves. From a strategic point of view, these new ventures provide them with significant supplies of ethylene, and to a lesser extent, of styrene, monomers and plastics with which they can compete on Afro-Asian and Southern European markets. For the price of their experience in petrochemical technology, these companies obtain raw materials, financing facilities, bulkproduction and strategic export bases.

3.2.3. Oil multinationals, as everyone is aware, are distinguishable by their substantial financial resources. Their indebtedness rates lie well below those of chemical companies, but they are investing heavily to extend their concentration in oil and gas to acquire an "all-energy" concentration.

Some Western experts fear that the international oil companies are deliberately refraining from looking for new oil supplies in unstable areas of the world, such as the Middle East, where prospects still look best. Whether this is true or not, it cannot be denied that they are directly interested and actively involved in research and development of new oil and gas resources in the North Sea, Alaska, parts of offshore Africa and the China Sea.

It is worth noting that plans are afoot in the International Energy Agency (IEA) to study whether or not oil companies are prospecting for oil in the right places[14]. Ultimately the coordination of the R & D efforts of US and European oil multinationals could be envisaged with those of their own home governments, according to IEA thinking.

According to Chase Manhattan sources, about $1.5 billion, or two-thirds of the additional capital spend by the world's 21 major oil companies in 1976, was related to the exploration and development of petroleum resources. As a proportion of total expenditure in 1976, 62% was concentrated in the United States, compared with 58% in 1975. In fact, energy diversification had been started by major oil companies many years before the 1974 crisis. This can be seen from the following tables.

TABLE A

U.S. Oil Multinationals and Companies' Involvement in New Energy Sources Before Oil Price Increases

Companies	1972 Turnover (before taxes) *in billion $*	Crude Oil	Gas	Shale-Oil	Tar sands	Coal	Nuclear Energy
Exxon	20.3	+	+	+	+	+	+
Shell	14.6	+	+		+	+	+
Texaco	8.6	+	+	+	+		+
Gulf Oil	6.2	+	+	+	+	+	+
SoCal	5.8	+	+	+	+	+	
Atlantic Richfield	3.3	+	+	+	+	+	+
Continental Oil	3.3	+	+		+	+	+
Ashland Oil	1.8	+	+	+			+
Sohio	1.4	+	+	+			+
Kerr Mc Gee	0.7	+	+	-			+

TABLE B

Companies'share in the Production of American Coal

Coal Subsidiary	Parent Company	Share of total US production
Peabody	Kennecott-Gulf Oil	12.5
Pittsburg and Midway Coal	Gulf Oil	1.3
Old Ben Coal	Standard Oil of Ohio	2
Monterey Coal	Exxon	0.2
Island Creek Coal	Occidental Oil	5.1
Arch Mineral Co.	Ashland Oil and Refining	0.2
Consolidation Coal	Continental Oil	10.8
		32.1

Source: The Chase Manhattan Bank: "Analysis of a Group of Petroleum Companies," New York, June 1973.

As oil becomes scarcer and more expensive, coal is expected to take over a number of tasks which oil performs today. The major international oil companies are ahead of the trend toward coal. For the last three years or more, they have been buying coalfields and coal rights whenever they could find investments on a suitable scale. Oil money is being used to mine coal in the U.S. and Australia, and negotiations are going on in several countries. Royal Dutch Shell has announced major new coal mining investments in South Africa as part of its policy to develop an integrated international coal business, both as producer and marketer. Over the next ten years, Shell is to invest well over $875 million in exploiting coal around the world.[15] Development of this kind might have a strong impact on the petrochemical industry's future move to coal-based feeds.

Oil multinationals are simultaneously investing, especially in the U.S., Northern Europe and Canada, to develop to the full their downstream operations (petrochemical manufacturing). On the basis of past and more recent practices, it is likely that their financial capacities are higher than has been assessed. The calculated lobbying for more profitable and efficient taxation and pricing policies by the governments of the U.S., Western Europe and Japan supports us in this conviction.[16]

An example of this trend can be seen in the following case. Canada's Imperial Oil Ltd., a 70% subsidiary of US Exxon, has applied to the Alberta Energy Resources Conservation Board for approval to build a $4 billion heavy oil recovery plant at Cold Lake on the northeastern shores of the province.

3.3. Marketing and Exporting Strategy Associated With the Joint Venture

Chemical refining, along with basic and intermediate processing, are the largest scale, and most capital-intensive of all petrochemical manufacturing stages. Indeed, it is largely at these very first stages of the industry that we mostly encounter the technical constraints and commercial implications of the economies of scale. Some developing countries, rich in oil and associated gas, are promoting huge basic processing capacities, thereby setting their sights on petrochemical exports for the mid-1980s. These countries are Saudi Arabia, Iran, Kuwait, Qatar, Libya and Venezuela.

3.3.1. Appraisal of Commercial Options Within Joint Ventures

When faced with exporting large, new, locally-manufactured production, developing countries have to choose between marketing these products independently or facilitating the emergence of new multinational channels and structures for marketing and distribution. As we have already seen, wherever a developing country enters into a joint venture, industrial promotion becomes a stimulus to, if not a base for, extending multinational manufacturing and trading channels.

Thus, the very definition and performance of future export policy become dependent on the multinational's commercial strategy. Most OPEC Countries sought the solution to their export problems in the marketing of products through multinational oil corporations or major petrochemical companies within the framework of joint venture projects. The question we may legitimately ask ourselves here, however, is whether those countries will actually ensure promotion of projects by making the choice, or will they rather cover their partners' risk by supporting the new petrochemical deployment of oil?

This is demonstrated by the 50-50 joint venture operation, entered into by the Saudi state-owned corporation SABIC and Shell, to build a complex in Yanbu, a petrochemical and industrial zone and harbour in Saudi Arabia. At least 1.5 million tons of LNG-derived naphtha produced in the complex from local raw materials will yield 450,000 tons of ethylene, 300,000 tons of caustic soda and styrene monomer, as well as 45,000 tons per year of ethylene dichloride. The complex is due to go on stream by the second half of 1981. Production will be largely export-oriented and Shell will handle marketing in Southeast Asia, Japan, Europe and the U.S. The above products are highly competitive, and there is known to be large potential for their marketing.

On the other hand, for petrochemical corporations associating with major oil exporting countries in the Gulf, the joint venture is an operation which can assist them to build export platforms close to raw material sources and nearer to existing or potential export markets. In other words, they "counterattack" in the highly competitive and crisis-affected petrochemical markets, while seeking at the same time to establish overseas manufacturing plant and extend markets.

An illustration of this can be seen in Saudi Arabia's SABIC joint petrochemical venture with the U.S. petrochemical corporation Dow Chemical. In order to establish a location in Jubail, another central petrochemical and industrial zone with harbour, Dow will run an ethylene-based petrochemical complex. Dow and SABIC will set up and run an ethylene-based petrochemical plant which will be export-oriented. By the mid-1980s, the plant will begin to produce ethylene at the capacity rate of 450,000 tons, with both ethylene glycol and low-density polyethylene being produced. Dow Chemical will be responsible for marketing these products and this will consolidate and strengthen its marketing overseas.

3.3.2.. Another significant joint venture is that operated by Qatar with the French state-controlled chemical company C.d.F.-Chimie. Located in the country's industrial zone of Umm Said, the ethylene-based complex will produce 300,000 tons per year of ethylene and 140,000 tons of polyethylene.

The small French chemical company, which owns just a 16% stake in the venture, will, nevertheless, be responsible for exporting production. Due to the size and limited means of this company, the joint venture can be seen as a strategic operation aimed at increasing funds, manufacturing capacity and market outlets. While stabilising and consolidating its position on the French domestic market, C.d.F.-Chimie is extending its export market by establishing an overseas manufacturing and exporting platform, which has been interlinked with a parallel domestic manufacturing joint venture in Dunkirk (France).

3.3.3. Alternative to Joint Venture-Linked Export Strategy

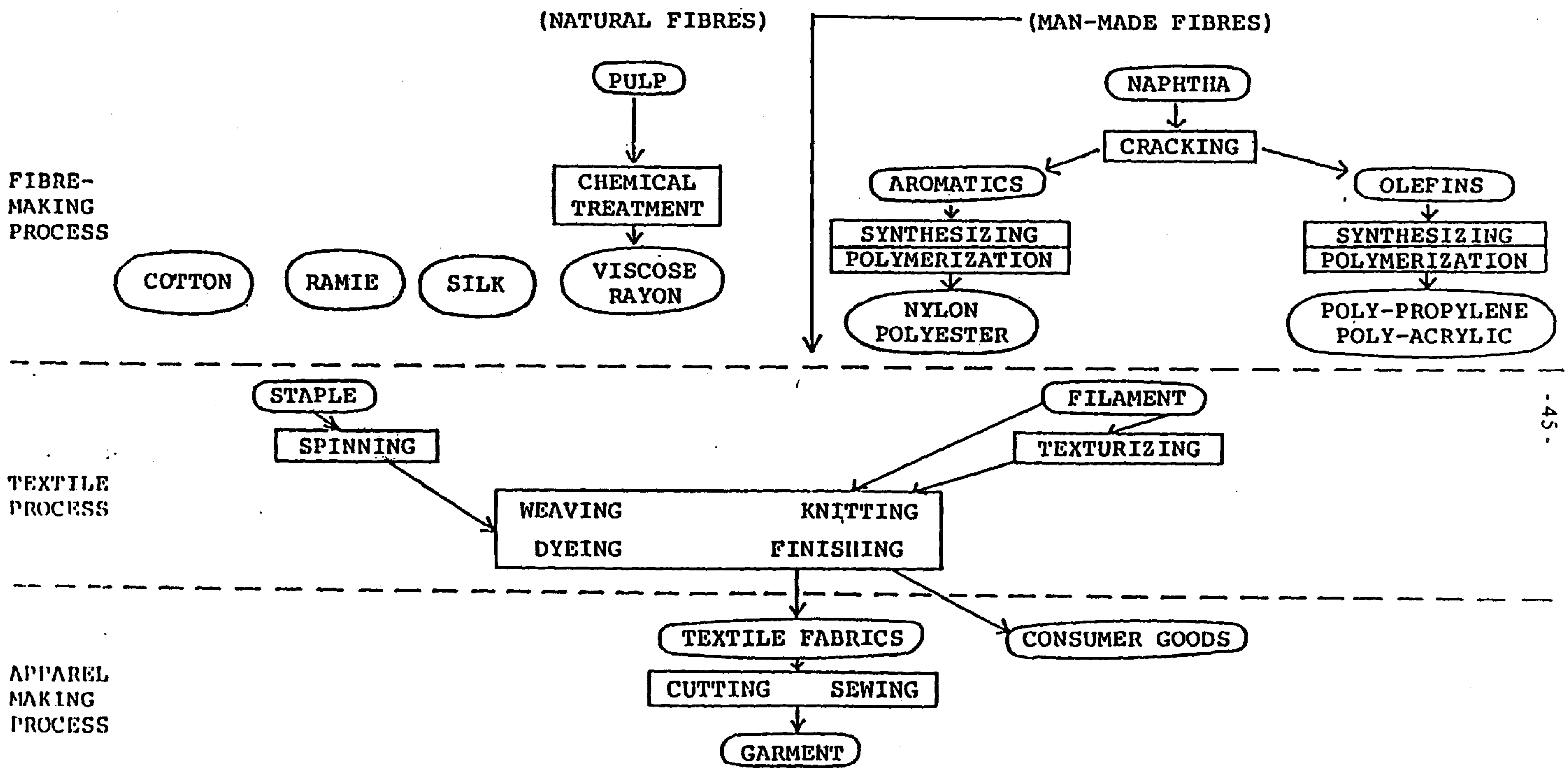
By entering into joint ventures with Western oil multinationals or increasingly multinational petrochemical corporations, oil and gas exporting countries of the Gulf alienate themselves from their legitimate right to decide later on their future commercial partners. Because of the divergent and contradictory strategic interests of their partners (in oil and petrochemicals; American, West European or Japanese), the Gulf states may find themselves victim of fierce and harmful intra-regional competition for export markets in the future. In fact, what they really need to do is to develop a courageous, far-sighted marketing policy based on state-to-state subsidised exports to potential markets in the developing and socialist countries. This could bring guarantees of lasting benefits, both for Arab and Gulf producers and to their potential partners, through a restructuring of the Arab region's halting integration, and the promotion and intensification of balanced, inter-regional, multi-product trade and financial cooperation.

3.3.4. Developed Market Economies' Subsidising of Petrochemical Exports

It is worth bearing in mind that, as in the case of Japanese steel and petrochemical plastics, governments of developed capitalist countries defend and support the export policy of their domestic petrochemical companies. While preaching free enterprise and advocating the market economy, those governments practice a "reverse protective policy" by subsidising exports of private petrochemical corporations. Authors dealing with industrial strategy regularly stress government subsidies to import-substituting or export-oriented manufacturing in the developing countries. But in the developed market economies, too, export subsidies have become commonplace. The U.S. Government and the European Economic Community (EEC) recently responded to protectionist claims of their respective steel industries so as to limit the degree and harsh effects of international dumping on manufactured goods markets brought about by the current economic recession and structural crisis.

In Great Britain, the state has subsidised feedstock supplies to major British private chemical companies, a typical example being the long-term North Sea gas supply deal recently made between the state-owned British Gas Corporation and the U.K.'s Imperial Chemicals Industries (ICI).

SYNTHETIC TEXTILE INDUSTRY : A CASE OF A PETROCHEMICAL SECTOR RUNNING "MATURE"



As far as U.S. petrochemical companies are concerned, these companies are able to make up for their financial deficiencies by extending their production capacities and markets through complementary internal and external joint venture strategies. Internally they are seeking investment financing or new chemical refineries and indirectly selecting sophisticated petrochemical products, in cooperation with financially strong oil multinationals and other major petroleum interests in the United States.

3.5. Major U.S. petrochemical companies are entering into joint venture operations with the principal oil and gas exporting countries of the Gulf, specifically in the fields of chemical refining and basic and intermediate processing of a typically capital-intensive type, with close proximity to raw materials and export markets. The financial contribution is as important here for those companies, as is the very high cost of transporting abandoned local raw materials.

3.5.1. With developing countries, both with oil and without, and which are or could be major consuming countries, U.S. petrochemical companies will probably increasingly follow the example of the Japanese, by establishing dynamic import-substituting overseas joint ventures with local interests in different downstream operations. Cheap labour and large consuming capacity are substitutes here for the local contribution to assets we saw in the preceding case. But that is the real challenge which they will have to take up when they try to sell in the highly competitive markets of Southeast Asia, Japan, East Africa and Southern Europe from their future export-oriented locations in the Gulf.

4. Transfer of Mature Technology Versus Technological "Rationalisation" and Revolutionary Innovation

We can see a plausible explanation for the exceptional transfer of fully integrated petrochemical production, not only to underpopulated countries such as Saudi Arabia and Kuwait, but also to oil-rich, well-populated countries such as Iran. The key explanation to such a transfer is the technological issue. Here we distinguish three phases or levels of petrochemical technology transfer:–

4.1. Phase I

"Mature" technology corresponding at a given moment of technological and manufacturing evolution to processes (and products) in the petrochemical industry, which is already well-known and applied on an extensive scale.

Although oil multinationals are already widely involved in chemical refining and associated with petrochemical activities (e.g. the fertiliser industry), they have not acquired the full technology applied in heavy petrochemical manufacture nor have they mastered its applied research with respect to full downstream operations. Of the Middle East's major oil producers, Iran started joint venture operations in the late 1960s[18], while Kuwait and Saudi Arabia (U.S. Dow Chemical with Saudi's SABIC, for example) moved in this direction after the 1973-74 crude oil price rises. All these developing countries which are trying to promote petrochemicals have one thing in common: the lack of a mature technological base. The best they can hope for in the 1980s is to acquire this technology before it becomes so mature as to tend towards obsolescence.

4.2. Phase II

Technological "rationalisation" or substantial improvement corresponding to a modified pattern of processing and manufacture, scheduled for the mid- or late 1980s. Through an active policy of heavy investment, major petrochemical companies are developing intense but selective research, designed to come up with new patterns of rationalised and improved processes, along with product specifications and performances. They are doing this on the basis of their solid experience and know-how of the last 30 years. The technological innovation of the last two decades has been largely concerned with the external physical aspects and commercial presentation of the end products, in order better to compete in a fluctuating cyclical market. This, in some way, bears out the famous Baran and Sweezy theory of a rising rate of profit and its consequent necessary, but partially unproductive, destruction. In fact, the major characteristic of recent innovation has been the relatively stable costs of raw materials. Fierce market competition, soaring feedstock costs due to partial, but substantial, loss of oil and naphtha rents since the beginning of the 1970s[19] and labour demands on the wage front, have all acted together to cause a decline – and not an increase – in the profit levels of the petrochemical industry. This state of affairs has been highlighted by all West European and U.S. companies.[20]

In contrast to Saudi Arabia, Iran has had several of its joint venture petrochemical (and other manufacturing) projects operating since 1966-68. For example, its joint venture with B.F. Goodrich for the manufacturing of PVC and liquid caustic soda started operating in 1966; in 1967 the Iranian–Amoco joint projected went onstream to produce sulphur and LPG. Nevertheless, U.S. petrochemical corporations like Dow Chemical, Du Pont and Union Carbide have projected petrochemical joint ventures with Iran only in the last ten years.

TABLE 2

WORLD PETROCHEMICAL MODEL – CLASSIFICATION OF PRODUCTS

FINISHED PRODUCTS MANUFACTURED IN DEVELOPING COUNTRIES

FIBRES

- Polyester
- Polyamides
- Acrylic

PLASTICS

- L.D. polyethylene
- H.D. polyethylene
- Polyvinyl chloride
- Polystyrene
- Polypropylene
- ABS resins
- Methanol based plastics

RUBBER

- Styrene butadiene rubber
- Polybutadiene

+

FINISHED PRODUCTS NOT MANUFACTURED IN DEVELOPING COUNTRIES

SOPHISTICATED FIBRES

- Polyvinyl alcohol and chloride
- Polypropylene

SOPHISTICATED PLASTICS

- Polyurethane
- Polyester
- Polyvinyl acetate and alcohols
- Acrylic
- Methyl methacrylate
- Epoxy polyacetal
- Others

SOPHISTICATED RUBBER

- Butyl rubber
- Polyisoprene, polychloroprene
- EPR, nitrile rubber
- Others

OTHER PRODUCTS

- Detergents
- Solvents
- Specialty Chemicals

→

BASE PRODUCTS EQUIVALENT

- ETHYLENE
- PROPYLENE
- BUTADIENE
- BENZENE
- XYLENE
- METHANOL

↓

RAW MATERIALS

- ETHANE
- LPG
- NAPHTHA
- GAS OIL

↓

TOTAL NEEDS IN T.O.E.

Due to the growing impact of feedstock and labour costs on total production costs, and to the increasing involvement of oil corporations and state enterprises in petrochemicals, petrochemical companies are now endeavouring to modify the pattern of manufacturing and processing in the industry. They will increasingly seek to reduce the quantity and cost of raw materials, both as energy and feedstock.[21] This implies the research and development of new processes and new end products. The latter are expected to be more competitive than are forthcoming mature products (to be manufactured by oil producing and non-oil producing developing countries) through existing processes. Hence, not only the physical external appearance of the products is to be changed, but also, in contrast to previously exclusive marketing innovations, the patterns of manufacturing and processing should be altered. This will put future products to be promoted by developing countries up against some stiff competition.

One substantial rule of the game associated with petrochemicals and other forms of industrial redeployment is to maintain on a dynamic basis differentiated technological development. This technological rationalisation and qualitative improvement is to be achieved through fundamental and qualitative changes in the technological and manufacturing patterns within the industry.

Basically, the direct cracking of naphtha is already applied in some pilot plans, and serious thought is being given to cutting out some of the intermediate processing stages and by-products so as to reduce the cost of the end product. New processes are to be developed under low heating conditions. All this will strengthen differentiated development both in technology and in petrochemical production between the developing countries, which have planned their petrochemical promotion, and the petrochemical industries of the developed nations, which are the home countries of the petrochemical corporations.

Even if we adopt the most optimistic of hypotheses, whereby developing countries succeed in acquiring and mastering the most up-to-date technology, by the time they achieve this objective, they will still lag behind the technological and manufacturing achievements of Western companies in the second half of the 1980s. In this last respect, the qualitative technological changes will be a sort of bridge to the third technological stage scheduled by major U.S. petrochemical corporations for the late 1980s and 1990s.

As to the future for oil multinationals and state-controlled oil companies involved in the petrochemical business, this will depend on the increasing interpenetration of the oil and petrochemical sectors and, more generally, on the degree to which oil interests become involved in petrochemical manufacturing and marketing, as well as on the capability of those oil interests to master heavy petrochemical technology and contribute to its rationalisation and innovation. Although this question is an important issue, it is outside the scope of this present paper.

4.3. Phase III

Petrochemical innovation through a new technological revolution.
Starting in the 1940s, Western oil companies abandoned carbon and adopted oil as a means to make greater profits from a raw material that was heavily underpriced. By the 1960s, the international industry (excluding the Socialist countries) had achieved the re-shaping of its petrochemical industry. As raw material costs have climbed, and labour demands increased, the industry has adopted a defensive posture. Since there is little chance of any change in the opposite direction at present, the industry, which consumes 6–7% of the world's hydrocarbons, deploys a technological strategy within the framework of hydrocarbons. But since oil prices are expected to start multiplying again from the mid-1980s, and substitute sources of energy and raw materials to be developed and exploited. the petrochemical companies have launched strategies for the development of synthetic oil and gas from coal and shale oil.

The major characteristics of the future petrochemical revolution will be the combined application of computer software techniques and lasers to obtain direct petrochemical fractions which avoid intermediate chemical reactions, eliminating by-products and heavy energy consumption in high temperature processes.

4.4. U.S. Union Carbide's Strategy for Feedstocks Up to the Year 2000 [22]

Major U.S. petrochemical corporations are reacting against the pressure on their traditional feedstocks whose costs are rising. They foresee the future of the petrochemical industry based on a new feedstock strategy and consequently on a technology to exploit alternative feedstocks.

The Chairman of Union Carbide believes that, as its traditonal feedstocks (crude oil and natural gas) become less economical, the future of the industry will depend on its ability to develop the new technology needed to exploit alternative feedstocks.

At present, oil and gas account for 98% of the feedstocks currently used by U.S. petrochemicals producers. The U.S. industry is almost totally dependent on hydrocarbons as feeds. According to Union Carbide's Chairman, economic and political forces are making these less attractive in the long run. Expectations of Union Carbide's Chairman are, in fact, the following:—

1. In the 1980s gas production will pick up.
2. In the 1990s oil output will taper off.
3. By the year 2000 oil and gas costs will converge and then exceed the costs of substitutes.

Hit by increased costs of its traditional feedstocks, Union Carbide has adopted a new technological strategy, thereby anticipating the predicted course of events. The strategy is applied through an orientation of the company's research and development programmes to provide the new technologies needed to develop these alternative feeds. The company's aim is to minimize feedstock costs and increase the competitive edge of petrochemicals.

According to Union Carbide, the alternatives now being considered could account for 10–15% of U.S. feedstock requirements by the year 2000 (but certainly not more than 25%).

Union Carbide foresees four phases of development of the various alternatives, corresponding to future gas peaks in the 1980s and the tapering off of oil in the 1990s:–

Phase I : In the first phase to 1984-85, efforts will be concentrated on more efficient use of crude oil as a feedstock, like the company's advanced cracking reactor, to go on stream by mid-1979, and also by the direct production of ethylene from atomized crude, using high temperature steam and combustion gases, with higher ethylene yield per barrel of crude and raw material flexibility.

Phase II : In the late 1980s, the strategic technological and manufacturing orientation of Union Carbide will be to increase production and use coal-based synthesised gas for methanol and ethylene glycol manufacture. It could replace natural gas and some petroleum feedstocks (that is, coal-based synthesised gas), representing around 25–30% of U.S. petrochemical feedstock use.

Phase III : By the 1990s, Union Carbide foresees crude oil production on the basis of shale oil and coal, but not in significant amounts. Even then, Union Carbide considers it unlikely that such a synthetic crude oil production will represent more than 5% of U.S. total crude use(*).

In other words, it is assumed in Union Carbide strategy that coal-based synthetic gas would cover more than one-fourth of the U.S. petrochemical feedstocks use in the late 1980s, and that crude oil to be produced from shale oil and coal would not represent more than 5% of U.S. total crude use.

(*) According to a recent U.S. Congressional study,[23] the Devonian Shale deposits of Appalachia in thirteen Eastern States could produce up to one trillion cubic feet of natural gas per year, or about 5% of current U.S. gas production, in the next 20 years. The Office of Technology Assessment study's estimates of potential production, set at 15–25 trillion cubic feet of natural gas, are less optimistic than previous estimates prepared by the National Academy of Sciences and the Energy Research and Development Administration (ERDA).

At the *third stage* of development, we can envisage total opposition between a conventional, "devalued" petrochemical technology in the oil and gas producing developing countries and a fundamentally different, revolutionary chemical technology supported by computer electronics, laser techniques and renewable non-conventional feedstocks in the developed world.

To return to our original question as to how we may shift the hierarchy of factors of production necessary to produce petrochemicals, we see that our analysis leads us to recognise the role of that part of labour which is crystallised into capital in the form of technology.[24] Playing a major role in the appraisal of the power relationship in a joint venture and consequently in the assessment of the imbalance in the distribution and use of its profits, technology is indeed privileged and decisive in any industrial redeployment. Because of the dynamic nature of the manufacturing and production processes, technology supports, promotes and stimulates the changing hierarchy of factors of production to the advantage of those who develop, apply and bargain with this technology. The scheme of the product cycle and mature products is no less dynamic, so that at each stage there will be imbalances between petrochemical (or other manufactured) products reflecting the peak of current technology, and mature products resulting from "devalued" processes and obsolete technology.

Planners of the oil exporting and other developing countries need to consider, when promoting petrochemical industries, the key future role which technology is going to play until the end of this century, as a differentiating and increasingly overpriced factor of production.

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[redacted] ceived, on an organisation chart, as the Six Stages of a Project. Bureaucrats in a number of other countries questioned whether their Washington colleague had got the chart quite right.

In Canberra, another city where government is the main industry, an amended version of the chart hangs in a ministry where the officials, having also seen numerous changes at political level, have decided that 'promotion of the non-participants' is not an apt description of the sixth stage and they have added a seventh stage.

For them, the seven stages of a project are: (1) Wild enthusiasm, (2) Disillusionment, (3) Total confusion, (4) Search for the guilty, (5) Punishment of the innocent, (6) Promotion of the guilty and (7) Recommencement of the cycle.

Watch Out

When time not only marches on but passes you by, the consequences can sometimes be disastrous, especially if you are in the time business itself.

So it was for the British watch and clock industry which was all but wiped out by cheap, reliable, mass-produced imports from Switzerland at the turn of the century.

There is a lesson to be learned by other industries from this story, so the opening of a clock and watch museum in Prescot, Merseyside [in the United Kingdom], by Professor A. J. P. Taylor . . . could well be described as timely.

Prescot once ticked along profitably as one of the world's principal centres for watch and clock components. A local invention for making cogs kept hundreds of little workshops busy for 200 years until cheap imports created a new mass market. Though the workshops then got together to form the Lancashire Watch Company, the craftsmen never adjusted to mass production and it was wound up in 1910.

Museum curator Loraine Knowles says there are still nonagenarians around who worked at the factory and recall with a shudder the quality of its five-bob product, the John Bull. The Swiss apparently avoided such problems by training people from scratch for their watch factories and letting their workshops, with their disdainful craftsmen, wither away.

The moral is obvious. But any negotiators of new technology agreements wanting to make the point to their work forces will find the museum, housed in a restored 18th Century town house, a bit cramped for coach parties.

From 'Men and Matters', *Financial Times*, London and Frankfurt, 30 April 1982.

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MOD 13 *

Newly Industrialising Countries in an Interdependent World

Colin I. Bradford Jr

THERE IS now a good deal of excellent literature that documents the increasing role of developing countries in world trade in manufactures.[1] Treating developing countries as a whole or using regional classifications, without country data, however, leaves open the possibility that all developing countries are seen as moving along a similar path and participating relatively (or potentially) evenly in the growth in manufactured exports. In fact, the country experiences have been quite different. In an earlier study based on the period 1966-73, Bela Balassa, of John Hopkins University, noted that twelve countries accounted for 84 per cent of the exports of manufactured goods from developing countries in 1973 and that 'no other developing country accounted for more than three per cent of the total'.[2]

RISE OF THE NEWLY INDUSTRIALISING COUNTRIES

In the period since 1973 there has been a further narrowing of the range of developing countries that are significant exporters of manufactures on a global scale. By 1976, the Republic of Korea, Taiwan, Hong Kong and Singapore accounted for over 90 per cent of the manufactured exports from East Asia; India, 75 per cent of manufactured exports from South Asia; and Brazil, Mexico and Argentina, 70 per cent of Latin America's industrial exports. Together, these eight newly industrialising countries accounted for over three quarters of the manufactured exports from the developing world in 1976.[3] There has been a considerable gap between these eight countries and what could be called the 'next tier' of developing countries, with Colombia, Malaysia, the Philippines, Pakistan and Thailand having been the

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next largest exporters of manufactures in 1976. It is clear that without the export capacity of these eight newly industrialising countries, manufactured exports of the developing countries would not have surfaced as a global trade issue in the late 1970s and early 1980s.

More recent data indicate that in 1979, manufactured exports from Korea, Taiwan, Hong Kong, Singapore and Brazil alone amounted to $53 billion (up from $18 billion in 1973) compared with $70 billion in total manufactured exports from all developing market-oriented economies in 1978 and with $51 billion in imports of manufactures by developed countries from non-oil developing countries in 1979. The four East Asian newly industrialising countries and Brazil have been the most dynamic and largest volume exporters of manufactures in the period 1973-79. Particularly if the special border trading arrangements between the United States and Mexico are separated out, Mexico, Argentina and India do not loom as large in global trade in manufactures as the four East Asian countries and Brazil. It is these five countries which emerged as the new powers in world trade in manufactures.

A review of the export experience of the newly industrialising countries reveals that the distinguishing feature of the Asian newly industrialising countries and Brazil is a historic shift in the public policy at a critical point in time to an export-oriented policy for growth which not only gave priority to manufactured exports but also made them the central focus of economic policy and development strategy.[4] Several elements were involved in each case. First, in Korea in 1964-66, in Taiwan in 1958-60, in Singapore in 1965 and in Brazil in 1967-68, there was a switch in policy from import-substitution to export-oriented industrialisation. Whereas Hong Kong had always been outward looking in the early 1950s there was a shift from an entrepôt function to industrialisation and industrial trade. Secondly, as part of these shifts, liberalised import and exchange-rate regimes were generally adopted, removing quantitative restrictions and surcharges on imports and suspending foreign-exchange controls. Thirdly, the exchange rate was in most cases unified, after a period of multiple exchange rates, and devalued and a realistic exchange-rate policy adopted in an attempt to avoid overvaluation that favoured imports. Finally, substantial export subsidies were created, in most instances across the board, in order to provide specific incentives for exports of manufactures.

The question that arises is how to weigh these various elements to arrive at an explanation of the dynamic performance of manufactured exports that has distinguished these few countries. The country experiences surveyed here seem to confirm earlier findings by Anne Krueger, of the University of Minnesota, based on the Korean and Brazilian experiences:

'The conclusion is not that export push itself accounts for all the difference in performance . . . ; it is rather that the logic of an export-promotion strategy seems to condition a number of other policies and to permit a number of other favorable factors to appear in a fairly systematic way.'[5]

In other words, export incentives alone do not explain the unusual performance. It is the commitment to the export-oriented policy by the government which makes it necessary to liberalise imports and exchange controls and to adjust the exchange rate in addition to providing export subsidies. The fact of the public policy commitment to export orientation drives policies in each of the critical areas — exchange rates, imports and exports. It is interesting that in the cases of sustained expansion of manufactured exports — Korea, Taiwan, Hong Kong, Singapore and Brazil — liberalisation of imports, exchange-rate adjustment and export incentives have prevailed *together* over a substantial length of time. What seems to be common, and indeed unique, to these five newly industrialising countries is a public policy commitment to policies for promoting growth through the export of manufactures which has entailed a holistic and internally consistent shift in the entire range of relevant foreign economic policies.[6]

It would appear that the underlying dynamic which has given rise to the problem is precisely the one which limits it. The phenomenon of newly industrialising countries has not arisen as a consequence of generalised forces of economic growth and industrial spread, but rather it is the result of the unusual convergence of a variety of forces and circumstances leading to industrial concentration. The implication would seem to be that whereas countries will indeed move along a continuum of dynamic comparative advantage with attendant changes in the composition of output and exports as growth in world trade and trade policies permit, these trends in growth will not by themselves yield quantum jumps in manufactured exports from an increasing number of new developing-country suppliers. New developing-country sources will surely appear, some achieving new status as exporters on a world scale. But the number will be limited and the occurrences will be unusual. The developed countries of the West are not facing a generalised phenomenon involving the developing countries as a whole; rather they are facing a special phenomenon which only a relatively few countries in any given period will be able to undertake and sustain.

GLOBAL ROLE OF THE NEWLY INDUSTRIALISING COUNTRIES

In the period since the initial oil-price rise the role of developing countries in the world economy has changed significantly. In the period since World

War II developing countries have depended on aid from developed countries to finance imports and on growth in developed countries to sustain their exports. In the period since 1973 much of the balance-of-payments surplus of the members of the Organisation of Petroleum Exporting Countries (OPEC) was recycled through private capital markets to developing countries in the form of medium-term financing of balance-of-payments deficits. The high-growth, high-exporting developing countries became the largest borrowers in this period due in part to their promising outlook in foreign-exchange earnings through exports. Together, the eight newly industrialising countries that generated three quarters of developing-country exports of manufactures in 1976 accounted for 40 per cent of the accumulated foreign debt of developing countries by 31 December 1979.[7]

The borrowing meant that this set of countries was able to grow faster than it would have otherwise and, indeed, in most instances faster than the developed countries. As a result, the high-growth, high-exporting, high-debt developing countries were able to sustain their demand for exports from the United States and other developed countries, especially in manufactures, and, in effect, provide some additional stimulus to growth of the developed economies in the period of serious recession (1974-75). The Organisation for Economic Cooperation and Development (OECD) calculated that the export surplus in trade in manufactures with third countries outside the OECD area rose from $53 billion in 1973 to $117 billion in 1975 and concluded that 'third countries in general, and among them the NICs [newly industrialising countries], thus provided considerable support to OECD manufactured exports in the recession'.[8]

Hence, in spite of the detrimental effect of the oil-price rise on the oil-importing developing countries, they were able to sustain their demand for manufactures. Even though oil rose from 12 per cent of developing-country imports in 1973 to 21 per cent in 1979, manufactures retained a 58-60 per cent share of developing-country imports over this period.[9] Developed-country exports of engineering goods rose from $23 billion in 1973 to $73 billion in 1979, the export surplus in these goods rising from $20 billion to $56 billion.[10] These data reflect an important growth in investment in non-oil developing countries during this period. If in fact the recycling of the OPEC surplus to developing countries had been used to finance consumption rather than investment, the growth prospects of developing countries would be bleak, debt-servicing capacity severely reduced and the trade gains for developed countries diminished. In fact, consumption growth in the non-oil developing countries fell from an average of 5 per cent in the period 1963-73 to 3.5 per cent in the period 1973-78, permitting the average annual growth in fixed investment to remain at 6.5 per cent.[11] These trends allowed developing-country investment and imports of machinery and transport equipment to remain high during these years of slow growth in world trade.

Hence the non-oil developing countries as a whole, and the high-growth, high-debt developing countries in particular, played a significant role in the post-1973 world economy by maintaining high growth rates, high investment rates and high import demand. In this sense the developing countries facilitated the overall adjustment of the world economy to rising oil prices by borrowing sufficiently to run trade deficits to offset the OPEC surplus and provide a margin of added growth to world trade as a result.[12] The question arises: can the developing countries continue to be a shock absorber for the world economy in the 1980s?

A variety of possibilities for the future exist, but in order to illustrate the nature of the problem, two broadly different scenarios might be imagined which have quite different implications for the nature of global interdependence in trade in manufactures.

One scenario envisages the high-debt developing countries reaching a point in the early 1980s where their debt-service payments become equivalent to the inflow of new loans and credits. This would mean that new borrowing would just be sufficient to offset debt-service payments on previous borrowing and not sufficient to finance additional imports. Import growth would then have to depend more directly on export growth. When this point is reached, the high-debt developing countries will have to make a transition from a period of debt-financed growth to a period of trade-financed growth. In a period of trade-financed growth, these developing countries will be rather more dependent on the growth rate of world trade and, in particular, on the growth of the United States and other developed countries as markets for their exports than they were in the previous period of debt-financed growth. This is a scenario fraught with difficulties due to the outlook for sluggish economic growth in OECD countries in the early 1980s. It implies (i) that the OECD countries need to be the engine of growth for the world economy and (ii) that the developing countries cannot continue to serve as a stabiliser for the international economic system.

Sir Arthur Lewis, in his Nobel Prize lecture,[13] poses the possibility of a different scenario, one based on an assumption of slower economic growth in the OECD countries -- what he calls the more developed countries. He assumes that exports of the developing countries need to grow at a rate of 6 per cent per year, whereas the more developed countries will increase their imports from developing countries by only 4 per cent per year. The only way the international trading system can accommodate these divergent, but likely, growth paths is for trade between developing countries to grow substantially, indeed by 11 per cent per annum.

As Sir Arthur Lewis put it:

'The problem is whether LDCs [developing countries] will persist in rapid growth despite the slowdown of MDCs [more developed countries]. If the economy is still dependent, the balance-of-payments weakness will pull it down; but if it has attained self-sustaining growth, the weakness in the foreign exchanges merely launches a drive to export to other LDCs, and the weakness in the balance of payments is then only transitional.

'If a sufficient number of LDCs reach self-sustaining growth we are into a new world. For this will mean that instead of trade determining the rate of growth of LDC production, it will be the growth of LDC production that determines LDC trade, and internal forces that will determine the rate of growth of production.'[14]

Clearly, this implies relative autonomy between developed and developing countries as opposed to relatively interlocking interdependence in the first scenario. These two scenarios raise the issue of what alternative inter-relationships are possible in the future.

ALTERNATIVE FUTURES

Of the two scenarios just put forward, one is illustrative of high interdependence between developed and developing countries and one of low interdependence. The high-interdependence scenario suggests that the degree of interdependence would increase to the extent that high-growth, high-debt developing countries make the transition from debt-financed growth to trade-financed growth. Their economic growth would then rest critically on the rate of growth in world trade which is determined largely by economic growth in the OECD countries. The low-interdependence scenario put forward by Sir Arthur Lewis would result from the combination of the likely slow growth of the OECD countries in the future and increasing South-South trade based on the autonomous capacity of developing countries to export manufactures. The rise of the newly industrialising countries illustrated the role of public policy in the emergence of a selected number of highly dynamic exporting countries. Market forces also play a role in determining changes in the patterns of comparative advantage.

How these four perspectives come to bear together on the future pattern of trade in manufactures can be usefully analysed by examining them in relation to assumptions about the prospects for growth in the OECD countries. Some of the highlights can be drawn together in a two-by-two chart (Figure 1) as a way of examining dimensions and implications of some of the recent forecasts and scenarios of international economic relations in

the 1980s. It should be understood that some of these are heuristic and illustrate by extremes the outer bounds of alternative inter-relationships.

The world trade scenario in the first quadrant of Figure 1 assumes, as does the Brandt Commission for example, that 'it is the OECD countries . . . which will have to be the principal outlet for future expansion of export-oriented industrial production in the South'.[15] The combination of successful recovery policies in the OECD countries and high North-South trade linkages would result in high rates of growth in the developing countries.

North-South interdependence

OECD growth		High	Low
	High	(1) High trade growth High LDC growth 'Ratcheting' Structural adjustment (*Interfutures Scenario A*) (*World Bank Base*)	(4) Regional trading bloc Protectionism Breakdown of free-trade system (*Interfutures Scenario D*)
	Low	(2) Slow trade growth Low LDC growth Static trade patterns Protectionism No structural adjustment (*World Bank Low*)	(3) High LDC growth High intra-LDC trade Slow intra-OECD trade Mutual autonomy (N-S) No structural adjustment Slower trading up (*Interfutures Scenario C*) (*Sir Arthur Lewis*)

FIGURE 1

These would determine the pattern of resource allocation within countries resulting in 'trading up' in the composition of exports to more skill-intensive and capital-intensive products as their endowments change or 'ratcheting' of countries into new 'tiers' as exporters of manufactures. This would be true of developed countries, as well as of developing countries, permitting them to experience dynamic export growth and relatively smooth structural adjustment internally.

The scenario in quadrant 1 is a highly optimistic one which relies primarily on the favourable policies and conditions prevailing in developed countries. In this respect, the outlook of the scenario for a high-growth and dynamic world economy is similar to the OECD Interfutures scenario of strong and converging growth in developed countries (Scenario A). This scenario has very steep requirements for it to come into effect: (i) the recovery of investment growth, (ii) the [illegible]eptance of st[illegible]ral [illegible]ment, (iii) co-ordinated demand-management policies, (iv) trade liberalisation, (v) massive financial flows to the Third World and (vi) policies to enhance energy conservation and supply.[16] This is a tall order indeed and implies 'the active control of change by governments' — perhaps a taller order still.

This scenario is quite similar to the one labelled 'requirements for faster growth' (RFG) that is projected by the World Bank for the 1980s in its *World Development Report* for 1981 (see Table 1). The requirements for the RFG scenario include a very high level of capital flows (both public and private) and the reduction or elimination of non-tariff measures affecting developing-country exports, in addition to the assumption embodied in the

TABLE 1

World Bank Growth Scenarios
(average annual percentage growth)

	1970-80	*1980-90*		
			Low	*High*
OECD GDP growth	3.3		2.8	3.6
World exports	5.3		3.7	5.7
Developing-country exports				
Total	4.6		3.9	7.6
Non-fuel primary	3.9		3.4	4.0
Manufactures	12.9		5.1	12.2
Developing-country growth		*RFG*[a]		
All developing countries	5.1	6.1	4.5	5.7
Middle-income (oil-importing)	5.6	6.2	4.3	5.6
Low-income (oil-importing)	5.1	4.5	3.0	4.1

Source: *World Development Report 1981* (Washington: World Bank, 1981) Tables 2.2, 2.3 and 2.7 and pp. 8-19.
[a] Scenario labelled 'requirements for faster growth', assuming higher capital flows plus reduced protectionism.

high-growth scenario that the developed countries will be 'relatively successful' in meeting the current challenges of productivity growth, inflation, unemployment and lagging output. The likelihood of this combination of circumstances occurring, as the World Bank indicates, is possible but not probable.

The real challenge of the 1980s is how to avoid the low-growth scenario which the World Bank projects will occur in the event of unsuccessful adjustment by the developed countries, lower capital flows and higher protectionism. These factors tend to have a reinforcing effect on one another and on their impact on the world economy. Slower growth in the developed

countries with higher unemployment tends to engender more protectionis[illegible] which slows down world trade and economic growth still further. Contra[illegible] tion constrains public budgets and prospects for private investment, so r[illegible] ducing capital flows. The result is mutually reinforcing slower growth, Nor[illegible] and South.

The impact of these factors on developing countries is particularly strikin[illegible] on the middle-income developing countries (see Table 1). Because of th[illegible] sensitivity of trade in manufactures to income growth and protection, manu[illegible] factured exports of developing countries would grow at over 12 per cent in [illegible] high-growth world economy rather than at 5 per cent in a low-growt[illegible] scenario. As a result, the economic growth of middle-income developin[illegible] countries shows the largest sensitivity to these changes, increasing from 4.[illegible] per cent to 5.6 per cent as the growth of the OECD countries and worl[illegible] trade accelerate. The World Bank estimates that roughly half the differenc[illegible] between low and high growth in gross domestic product (GDP) in middle[illegible] income countries is attributable to slower growth in the OECD countrie[illegible] and lower capital flows and that a little less than half the difference is due t[illegible] protectionism and poorer performance in the developing countries themselves.

If the slower-growth scenario were to occur, as in quadrant 2, under conditions of high North-South interdependence, slower growth in world trade and lower growth in the developing countries would be expected. Changes in the product composition of world trade would evolve more slowly as protectionism and resistance to structural adjustment became the norm. Given the pressures exerting themselves on the newly industrialising countries, their economies would come under strain as slower trade growth would fail to provide the impetus for internal transformation to move to the next stage of industrialisation and exports. This strain would not only dampen the demand of the developing countries for imported capital goods and other OECD exports; it would also create balance-of-payments difficulties, so aggravating their debt problems. In the face of these circumstances, more restrictive import policies of the newly industrialising countries would undoubtedly be imposed, further hampering the growth outlook for newly industrialising countries and their contribution to world trade. Protectionism in developed countries would undoubtedly focus on labour-intensive manufactures as unemployment worsened, thereby dampening the export drives of the 'next tier' of developing countries, forcing them back to primary-product exports and to import-substitution policies. In the World Bank's low-growth scenario manufactured exports from the developing countries grow by almost 60 per cent less in the 1980s than in the period 1970-80. This puts tremendous pressure on the outlook for developing-country industrialisation and trade. Slow growth and protectionism would lessen the adoption by developing countries of export-oriented policies for growth, shrinking their capacity for debt servicing and for increasing imports.

If it is assumed that this scenario is unacceptable to developing countries, the logical strategy for them to pursue is one of emphasising South-South trade (quadrant 3). If Sir Arthur Lewis is right, and developing countries can become the engine of their own growth, this scenario would lead to high developing-country growth and a high level of trade between developing countries. He postulated a developing-country growth rate of 6 per cent as plausible with a growth rate of 4 per cent in developed-country imports, providing trade between developing countries grew by 11 per cent. But this rate of trade between developing countries is almost half again as high as the growth rate of developing-country trade in the World Bank's high-growth scenario. One would imagine trade between OECD countries to be slower in this scenario, due to slower growth in the OECD countries, the multipliers affecting economic activity operating downward in a reverberating fashion just as they do in the upward direction. The international division of labour would proceed more slowly. Trade between developing countries would require less vigorous structural transformation than would patterns of trade between the OECD and developing countries; and the OECD countries would feel less pressure to phase out labour-intensive industries.

If this scenario were taken to its extreme, it would entail a virtual break in North-South trade relations as an effort was made to achieve greater independence, particularly on the part of the South. This would be the equivalent of the North-South breakdown scenario (Interfutures Scenario C). This scenario projected intra-OECD trade increasing to 45 per cent of world trade in manufactures from 36 per cent under its low-growth scenario (Interfutures Scenario B-2), trade in manufactures between developing countries increasing to 13 per cent from 6 per cent, with developing-country imports from developed countries dropping from 20 per cent of world trade to 10 per cent and developed-country imports of manufactures from the developing countries declining from 12 per cent to 5 per cent.[17] The interesting aspect of this scenario is the degree to which developed-country rates of growth are affected by this path of mutual autonomy. Japan and the countries of Western Europe are particularly hard hit because of their dependence on imported raw materials, their readjustment bringing down the overall growth rate of developed countries to 2.3 per cent.

In a slow-growth, protectionist and politicised world, the logical strategy would be a strategy of preferential trade with specific sets of countries which serve interests and needs most directly and protectionism against all others. This would be a world of trading blocs in which national governments would seek to regulate trade in terms of national interest and the multil eral arrangements would be overturned. This is a scenario (Scenario D Interfutures) which improves rates of growth and trade flows in comparis with a North-South break, but which qualitatively destroys the internatio trading system as it is known today.

The four scenarios are illustrative of different combinations of outcom resulting from different assumptions about economic growth and interd pendence. Moving from one set of conditions to another is not simply matter of conscious choice, but depends on causal factors which can gen ate the alternative outcomes. The key variable in the interdependent eco omic growth of the late 1970s has been the recycling of OPEC savings to t developing countries in the form of increased investment largely throu imports of capital goods from the United States and other develop countries. The availability of investment financing for the developin

TABLE 2

OPEC Exports and OECD Oil Imports
(million barrels per day)

	1977	*1978*	*1979*	*198*
OECD (7 majors*) net oil imports	21.4	20.5	20.9	19.
OPEC net oil exports	29.3	28.0	28.4	25.5
OECD/OPEC (%)	73.0	73.2	73.6	74.5

Sources: *Economic Outlook*, OECD Secretariat, Paris, December 1979, Table 53, p. 124; and *World Economic Outlook* (Washington: International Monetary Fund, 1980) Table 33, p. 112.
* United States, United Kingdom, West Germany, Japan, France, Italy and the Netherlands.

countries depended on sufficient growth in the OECD countries to sustain OPEC oil exports at a high enough level to generate a surplus over OPEC imports. In this sense, the inelasticity of demand for oil generated forced savings from the OECD countries which accrued to OPEC and were recycled as investment in developing countries. This pattern of global interdependence and adjustment worked well throughout the 1970s, as can be seen in Tables 2, 3 and 4.

The seven large OECD countries accounted for nearly three quarters of OPEC oil exports in the period 1977-80 (see Table 2). The trade deficit in fuels for the developed countries was offset by their trade surplus in manufactures in the period 1973-79, which was absorbed in roughly equal proportions by the non-oil and the oil-exporting developing countries (see Table 3). Whereas the oil-exporting developing countries financed their deficit in manufactures through exports, the non-oil developing countries financed their deficit in manufactures through increased demand. The current-account deficits of the non-oil developing countries represented 92 per cent of the OPEC surplus in the period 1974-81 (see Table 4). The recycled OPEC surplus was used by the developing countries, particularly the newly industrialising countries, to increase imports of capital goods from OECD countries, augmenting investment and developing-country economic growth. These patterns of interdependence and adjustment were mutually consistent and self-reinforcing, enhancing world trade and economic growth.[18]

The principal factor which constrains the working of these patterns now is the economic slowdown in the United States and the countries of Western Europe. The patterns work in reverse. Slower growth in the OECD countries generates a smaller OPEC surplus, reducing 'the pool of world savings' (William Branson's term), leading to less borrowing by the newly industrialising countries, so reducing their imports of capital goods and commensurately reducing the growth of developing and OECD countries. The

TABLE 3

Trade Balances in Manufactures by Major Areas
(billion dollars f.o.b.)

	1973	*1974*	*1975*	*1976*	*1977*	*1978*	*1979*
Industrial countries							
Fuel	−36	−110	−102	−123	−133	−130	−184
Manufactures	53	90	116	115	130	154	170
Non-oil developing countries							
Manufactures	−27	−43	−47	−40	−46	−56	−71
Oil-exporting developing countries							
Manufactures	−15	−26	−44	−52	−64	−75	−73

Source: *International Trade 1979-80* (Geneva: GATT Secretariat, 1980) p. 8.

result is that the slow growth of the West limits both the possibilities for debt-financed growth of the developing countries, by reducing global savings, and the possibilities for trade-financed growth of the developing countries, by diminished demand for developing-country exports. The feasibility of the developing countries continuing to play a major role in global adjustment through interdependent patterns of rapid economic growth is limited on both the demand and the supply side.

Sir Arthur Lewis's optimism about the possibility that trade between developing countries can replace North-South trade must be viewed with some scepticism not only because of the limited results obtained from previous efforts to promote South-South trade and economic integration of the developing countries but also because the assumption of 'self-sustaining growth' based on domestic savings must hold for it to be 'the growth of LDC production that determines LDC trade'. Neither the non-oil developing countries as a whole nor the newly industrialising countries appear to have

TABLE 4

Summary of Current-account Balances, 1973-81
(billion dollars)

	1973	*1974*	*1975*	*1976*	*1977*	*1978*	*1979*	*1980*	*1981*	*Total 1974-81*
OPEC	6.6	67.8	35.0	40.0	31.1	3.3	68.4	112.2	96.0	453.8
Non-oil developing countries	−11.5	−36.8	−46.5	−32.9	−29.6	−37.1	−56.1	−80.4	−96.5	−415.9
Developing countries/OPEC (%)		54.3	132.9	82.3	95.2	—	82.0	71.7	100	91.6
Industrial countries	103.	−12.4	17.1	−2.1	−5.5	30.1	−10.7	−44.0	−29.5	
Industrial countries/OPEC (%)		18.3	..	5.3	17.9	—	15.6	39.2	30.7	

Source: *World Economic Outlook*, Occasional Paper No. 4 (Washington: International Monetary Fund, 1981) Table 14, p. 123.

reached the point of independence from the flow of foreign capital or from the imports of capital goods. Hence the scenario of low interdependence and a high developing-country growth rate also seems very unlikely.

CONCLUSIONS

It must be concluded that the OECD and developing countries face options for the 1980s which are limited to those of an interdependent world economy. The problem for both is that interdependence reinforces prevailing trends: high growth in one area spurs higher growth in the other and, unfortunately, the converse is also true. We seem to have come to the end of a period in which debt-financed growth of developing countries could coexist with and cushion sluggish growth in the developed countries. If there is to be a pattern of mutually reinforcing growth in the 1980s, it would seem that the developed countries will have to take the lead.

The pressures of the current economic difficulties facing the United States and the countries of Western Europe are considerable. The domestic economic adjustments required to deal with inflation, unemployment, low rates of investment, slow productivity growth and, hence, sluggish economic performance are of major consequence and the first priority. But the foregoing should make it clear that these domestic adjustment problems are the sources of international adjustment difficulties in advanced countries and not the converse. To view imports of manufactures from developing countries as isolated causes of problems in the developed countries and to attempt to deal with them apart from domestic difficulties is to misperceive the present challenge facing the United States and the countries of Western Europe.

It is precisely the fact that the economic policies required in the West today are not simply those of traditional stimulation of demand, but rather must address the problems of productivity growth, technical change and investment patterns that priority attention to these domestic issues would make the most significant contribution to the world economy. To be sure, faster demand growth in the OECD countries could ease the structural strains of lagging sectors of the West and add to world trade and economic growth. But economic policies aimed at stimulating productivity and investment would bring about dynamic structural transformation, deepening comparative advantage. This would not only ease the transfers of resources from lagging sectors to growing ones in advanced economies; it would also spur the growth of the international division of labour, accelerating the change in composition of trade and production internationally that all economies need if they are to progress.

Macro-economic structural adjustment policies by the OECD countries would facilitate the growth of competitive export industries which employ more efficiently the idle resources of lagging sectors, thereby easing the ability of the West to import more labour-intensive goods from the 'next tier'. Dynamic export growth would also increase the import capacity of the OECD countries overall for goods from more skill-, technology-, and capital-intensive industries in the newly industrialising countries and within the OECD countries. These policies would do more than result in high rates of economic growth and greater world trade; they would facilitate structural transformation globally, which is the most urgent need of world economic adjustment in the 1980s. This suggests a form of interdependence in the 1980s in which domestic policies are more important in affecting global conditions than foreign economic policies in the narrow sense.

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1. This article draws upon work by the author for two research projects on the newly industrialising countries: one under the auspices of the Royal Institute of International Affairs, London, financed largely by the German Marshall Fund; the other sponsored by the United States Agency for International Development.

2. Bela Balassa, 'Export Incentives and Export Performance in Developing Countries: a Comparative Analysis', *Weltwirtschaftliches Archiv*, Vol. 114, No. 1, 1978, pp. 24-25. The countries are Argentina, Brazil, Chile, Colombia, Hong Kong, India, Israel, Korea, Mexico, Taiwan, Singapore and Yugoslavia.

3. Calculated from Donald B. Keesing, *World Trade and Output of Manufactures: Structural Trends and Developing Countries' Exports*, World Bank Staff Working Paper No. 316 (Washington: World Bank, 1979) Annex B. (Manufactures are defined in terms of Standard International Trade Classification [SITC] 5 to 8 minus 68 [non-ferrous metals].)

4. See Colin I. Bradford Jr, 'The NICs in Global Perspective', in Louis Turner *et al.*, *The Newly Industrializing Countries: Trade and Adjustment* (London: Allen & Unwin, for the Royal Institute of International Affairs, 1982); and Bradford, 'Advanced Developing-country Manufactured Export Growth and OECD Adjustment', a paper presented at the Eleventh Pacific Trade and Development Conference on 1-4 September 1980 in Seoul, Republic of Korea, published in Lawrence B. Krause and Wontack Hong, *Trade and Growth of Advanced Developing Countries in the Pacific Basin* (Seoul: Korean Development Institute, 1981).

5. Anne O. Krueger, *Foreign Trade Regimes and Economic Development: Liberalization Attempts and Consequences* (Cambridge, Mass.; Ballinger, for the National Bureau of Economic Research, 1978) p. 282.

6. It should be noted, however, that there is variety in the trade conditions and trade policies of these countries with Hong Kong engaged in a *laissez-faire*, free-trade regime, Singapore with an interventionist free-trade orientation and Taiwan, Korea and Brazil having interventionist trade policies which may either fall short of or overshoot the optimality point and therefore could be labelled 'deviationist'. See Krause, 'Conference Summary', in Krause and Hong, *op. cit.* The point here is that whereas export-oriented growth policies on the whole are probably less distorting than import-substitution policies, they are not free of bias and can in fact overdo incentives for exports, creating greater adjustment problems than a less interventionist approach to the international division of labour would warrant. The issue of the extent to which export subsidies of developing countries go beyond the point of compensating for discrimination against exports and over-subsidise developing-country exports is a legitimate and significant international issue.

7. *Annual Report 1981* (Washington: World Bank, 1981) pp. 134-36. The eight countries are Korea, Taiwan, Hong Kong, Singapore, Brazil, Mexico, Argentina and India.

8. Secretary-General of the OECD, *The Impact of the Newly Industrialising Countries on Production and Trade in Manufactures* (Paris: OECD Secretariat, 1979) Table 9, p. 29.

9. *International Trade 1979-80* (Geneva: GATT Secretariat, 1980) Table 15, p. 50.

10. *Ibid.*, Table 6, p. 10.

11. *Ibid.*, Table 11, p. 31.

12. For a more complete analysis, see Bradford, 'The NICs and World Economic Adjustment', *loc. cit*

13. Sir Arthur Lewis, 'The Slowing Down of the Engine of Growth', *American Economic Review*, September 1980, pp. 555-64.

14. *Ibid.*, p. 562.

15. Independent Commission on International Development Issues, *North-South: a Programme for Survival* (London and Sydney: Pan Books, 1980) p. 175.

16. *Interfutures: Facing the Future — Mastering the Probable and Managing the Unpredictable*, report of the Interfutures project (Paris: OECD Secretariat, 1979) p. 302.

17. *Ibid.*, p. 332.

18. Bradford, 'The NICs and World Economic Adjustment', *loc. cit.*; and William H. Branson, *The OPEC Surplus and US-LDC Trade*, Working Paper No. 791 (Cambridge, Mass: National Bureau of Economic Research, 1981).

'Economic laws have a way of taking their own revenge on those who break them.' — attributed to Stanislaw Gustavovitch Strumlin (1877 1974)