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DOMESTIC TECHNOLOGY GENERATION IN LDCs:

A REVIEW OF RESEARCH FINDINGS

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CONTENTS

I. INTRODUCTION

Technological Change in LDCs has both an external as well as an internal origin, i.e. is based on technical knowledge and information coming from foreign and from local sources.

Foreign technological knowledge often comes 'embodied' in imported machinery and equipment. It also flows in as 'blue-prints', patents, instruction manuals, and other such 'disembodied' technical documents frequently to be found as part and parcel of licensing agreements and technical assistance contracts. The economics of importing foreign technology -its advantages and costs both at the private and social level- has been extensively examined during the course of the last decade and will by and large remain out of the scope of the present paper. 1/

Contrary to such picture much less attention was given by the profession to the economics of domestic technical knowledge generation in LDCs. The received theoretical heritage is in part responsible for such state of affairs. Conventional production theory is based upon the assumption that technical information is freely and instantaneously accessible to every other economic agent. Much of the technological problem is in such a way simply assumed away without exploring it.

At the international level the ideas concerning the diffusion of technical knowledge and information have also been rather simplistic up until very recently. The notion of the technology 'shelf' stocked somewhere in libraries and archives of universities and manufacturing firms of the developed world and just waiting to be used by any odd LDC has been the standard idea with which economists approached the study of technological change in developing nations. More frequently than not such view was also complemented by the assumption of an almost complete passiveness from the part of the recipient society, as if no domestic technical knowledge generation could be expected to emerge in LDCs.

Very few people would today doubt that such an extreme description of the relationship between industrialization and technological change in LDCs leaves many unanswered questions. This is so for at least two different sets of reasons. On the one hand, the argument rests on a highly unrealistic perception of what a technology actually is. On the other hand, such view of technological change in LDCs does not capture the very large differences that prevail among developing nations in terms of availability of domestic engineering and entrepreneurial skills which either adapt to the local environment technologies imported from abroad or generate new technological packages of their own.

1/ With respect to technology imports, its advantages and shortcomings, the reader can see: a) C. Vaitsos, Intercountry Income Distribution and Transnational Enterprises. Clarendon Press, Oxford, 1974; b) D. Spencer & A. Woroniak, The Transfer of Technology to Developing Countries. Frederick A. Praeger, Publishers, New York, 1967; c) Jorge Katz, Importación de Tecnología, aprendizaje e industrialización dependiente. Fondo de Cultura Económica, Mexico, 1976, etc.

The purpose of the present paper is to review some of the research findings obtained during the course of a four year long exploration into the economics of technology generation in LDCs. Individual firm and industry studies were undertaken by a team of economists and engineers in some of the major Latin American countries in order to throw some light upon: 1. The rate and nature of the domestic technology-generating efforts carried out by different companies and manufacturing sectors. 2. The macro and micro variables which affect such knowledge-generating efforts.

Section I of the paper briefly looks at the theoretical background underlying much of the work to be reviewed. Quite a lot has happened in this field of enquiry since the days in which 'technology' was regarded as an exogenous force -a sort of deux ex machina- about which economists had little or nothing to say.

Let us begin by defining 'technology' as a package of technical information useful in the production of a given good or service, i.e. let us think of it as a factor of production in its own right. Various peculiarities of such factor of production, have been noted in the literature. Consider some of them.

Firstly, in as much as it has some of the properties of the so called 'public goods', technical information is indeed a very special factor of production. The usual rules concerning competitive resource allocation become inapplicable and questions of appropriability, of optimal patterns of investment, of divergence between social and private costs and benefits, etc. come up and have to be dealt with both at the conceptual and policy levels. It is important to notice, however, that developed countries might fare rather differently concerning this property of technical information. In so far as LDCs concentrate their technological search efforts on the applied engineering end of the knowledge spectrum -vis a vis new knowledge generation in the basic sciences- some of the resource allocation difficulties which derive from the public good character of this factor of production might be less serious in developing nations than in advanced industrial societies.

Secondly, rather than being exogenously given and freely and instantaneously accessible to everybody, new technical knowledge and information has to be systematically sought for by manufacturing firms. This obviously implies time and cost in as much as firms need to engage themselves in technological search efforts of various different sorts. Such search efforts are: a. highly sensitive to the micro and macro atmosphere and market regime in which firms operate, and, b. highly idiosyncratic of the particular enterprise which undertakes the search.

Thirdly, a package of technical information is almost never: 1. completely and taxatively specified, 2. perfectly understood and 3. easily replicable. Rather, as R. Nelson has pointed out, there is a large element of tacitness, inimitability and imperfect understanding underlying the notion of technical knowledge. 2/

2/ R. Nelson, Innovation and Economic Development: Theoretical Retrospect and Prospect, Working Paper N°31, IDB/ECLA/UNDP Research Programme on Science and Technology, Buenos Aires, April 1979.

All of the above mentioned aspects -peculiarities of technical knowledge as a factor of production, nature of the technological search process, etc.- will be examined in Section I of this paper in order to set up the theoretical background of the research results which we shall be reviewing in the remaining sections of this essay.

Section II looks at the received literature as from the perspective of LDCs. Much of such literature comes from studying the economic system and the innovative atmosphere of developed industrial societies. It is by no means obvious that such a background provides the right kind of perspective to help us understand the economics of technological change and innovation in less developed countries. LDCs are indeed different from DCs in aspects such as market size, degree of tariff protection, availability of skills, market and information distortions, etc. Such differences continuously flash out specific signals which, to a greater or lesser extent, reach the entrepreneurial community and induce particular responses from their side. As far as technology is concerned their response to the above mentioned structural features takes place at least at two different levels. On the one hand, in relation to choice of technique, i.e. in connection with the technological package originally chosen by industrial firms to begin operating in a LDC environment. On the other hand, the above mentioned distinctive structural features of LDCs greatly affect both the rate and nature of the locally-undertaken technological search efforts, i.e. the generation of new technical knowledge and information. In neither of both spheres -i.e. choice of technology and domestic technological search efforts- the behaviour of manufacturing firms in LDCs is likely to be close replica of behavioural patterns of industrial firms in more developed countries. Rather, the specificity of the local physical, social and economic environment and the intrinsic irreplicability and imperfect understanding of technical information, both will account for the fact that neither the initially-chosen production function nor changes of technique introduced through time, are likely to be similar across countries.

Having brought home the notion that both the initial choice of technique and the rate and nature of subsequent technological search efforts are likely to differ quite significantly as between DCs and LDCs, Section II of the paper examines the following aspects: a. Rate and nature of the local technological search efforts undertaken by manufacturing firms in LDCs. b. Macro and micro variables which influence entrepreneur's behaviour in this field. Throughout this Section we make extensive use of research findings reported in various case studies of the IDB/ECLA/UNDP Research Programme on Scientific and Technological Development in Latin America. Such evidence seems to indicate that the technological path of a given industrial plant is 'evolutionary' in nature and should be studied as a time-dimentional process and not as a state or condition. The rate and nature of technical change, as well as the type of innovations and productivity advances to be sought for by a given enterprise at a certain point of time, strongly depend upon: a. strictly microeconomic forces emerging from the specific history of the firm; b. market variables describing the competitive environment in which the firm operates; c. macroeconomic forces characterizing the broad parameters of the system in which both the firm and industry are inmersed and, finally, d. the evolution of the knowledge frontier, or 'state of the art' at the international level.

II. ON THE THEORY OF INNOVATION AND TECHNICAL CHANGE

II.1 Technology and the market mechanism

Let us begin by defining a production technique as a package of technical information indicating how to perform a given economic activity, i.e. the production of a good or service. Such package of technical information will normally consist of: a. The design and engineering specification of the product (or service) in question. b. A production process, or basic manufacturing routine and, c. An industrial organization arrangement (degree of vertical integration, patterns of subcontracting, etc.). Information on all three of these different technical levels will be required in order to perform any economic activity.

The above definition of a production technique is somewhat broader than the one normally employed by the profession which is basically limited to the notion of a given capital/labour ratio, i.e. to the specific production technique or manufacturing routine needed to carry out the activity. In other words, the conventional definition of a production technique looks at the particular combination of men and machines required by the activity without paying much attention to aspects concerned with product design or industrial organization. Our broader definition will permit us later on to bring into focus a whole range of important questions concerning the 'production function' of new technical information, questions which are rather difficult to examine within the tight limits imposed by the conventional factor proportion approach.

It follows from our previous definition that technical change is any change in the package of technical information employed be a given firm and that such change could be related to any one of the three previously characterized areas: that is, it can involve a change in product design, in the production process and/or in the industrial organization routine followed by the plant.

At variance with conventional production theory, which assumes that the flow of new technical information is exogenously given to the firm, and is instantaneously and freely accessible to everybody, we shall now examine a number of special characteristics which make of technical information a very particular factor of production indeed. 3/ As a result of such characteristics the usual theorems on the efficiency of competitive resource allocation become inapplicable. The amount of technical information which would be produced and disseminated under competitive rules is bound to be non-optimal and rules for optimal intervention need to be explored.

3/ Concerning such characteristics we shall extensively draw upon the paper by J. Stiglitz and P. Dasgupta: "Market structure and the nature of innovative activity" presented at the IEA Conference on Economic Growth and Resources, held in Tokyo in August 1977.

a. Technical information as a public good

Unlike other commodities "if one person gives another person a piece of information it does not diminish the amount of information that the first person has". 4/ As with other public goods competitive markets will normally lead to undersupply.

b. Imperfect appropriability and suboptimal dissemination

In spite of having some of the features of a public good, technical information is only partially so in as much as there are methods -patent rights, secrecy, etc.- for the appropriation of returns. Such methods, however, restrict dissemination and lead to suboptimal aggregate utilization of technical information and to static inefficiency in resource allocation.

c. Increasing returns to the use and production of technical information

Returns to the generation of technical information will be larger the larger the scale of production, as the same piece of information can be used at any scale of output. Thus, the unit cost of technical information decreases as the scale of output increases. As for the production side of technical information, there seems to be a minimum threshold before which it just does not pay to search for new technical information. Beyond such threshold increasing returns seem to underlie the generation of new technical information. 5/

d. The common pool property

In so far as the production of technical information normally draws upon a common pool of preexisting technical knowledge, some of the returns to the former actually constitute rents on the latter. As in other cases of common pools this situation might lead to excessive entry. It is also true, however, that the benefits of producing technical information are not normally captured in its totality by the agent that performs the search effort and therefore technical search activities contribute to the common pool as well as take out from it. The net balance is difficult to judge a priori.

e. Uncertainty

Assume the search for new technical information is viewed as drawing successive samples from a given distribution of potential incremental units of technical information. There are two sources of uncertainty in a situation of this sort. On the one hand, the distribution of potential incremental units of new technical information may be well defined, but it is more likely that the decision maker will not know them with certainty. He may have expectations

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4/ J. Stiglitz and P. Dasgupta. Op.cit.

5/ J. Stiglitz and P. Dasgupta. Op.cit.

about them from his previous knowledge of the field, but these will represent a subjective probability distribution of potential gains. On the other hand there is the variance of the expected increases in technical information. This one would exist even if the underlying distribution were known with certainty.

The fact that there is uncertainty concerning both the distribution of all possible search efforts, and their potential outcomes, precludes the existence of a full set of risk markets as are required by the theorems establishing the optimality of competitive market allocations.

The above mentioned characteristics not only lead to the amount of new technical knowledge and information which would be produced and disseminated in a competitive situation non-optimal, but they also make it unlikely that perfectly competitive situations will prevail.

The actual incidence of many of the above mentioned properties strongly depends upon the type of new technical knowledge and information we consider. Basic scientific knowledge fares very differently from detail engineering knowledge in terms of appropriability, uncertainty, etc. In so far as LDCs. concentrate their tecnological search efforts on the applied engineering end of the knowledge spectrum, some of the above mentioned properties might have a lesser impact upon resource allocation in LDCs than the one they presumably have in developed industrial societies. The nature of market failure -and the public policy package which would be required to counteract such failure- will clearly differ as between DC and LDCs. 6/

In addition to the previously examined properties R. Nelson has recently singled out three other aspects of technical information which have thus far remained unnoticed in the literature. Such features are: a. a certain amount of tacitness, b. some degree of inimitability and, c. incomplete understanding. In Nelson' words: "To the extent technologies are tacit, firm production sets are fuzzy around the edges. To the extent that imitation is not trivial, the idea of an industry wide production set the elements of which are accessible to all firms is a misleading abstraction. To the extent that technologies are not well understood, sharply defined invention possibility sets are a misleading concept and interaction between learning through R and D and learning through experience is an essential part of the invention process. These aspects -tacitness, inimitability, and low level of understanding- clearly are not orthogonal but well may go together. I have used the term "tacit" to refer to uncertainty regarding the range of available techniques for production, and

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6/ This point has been recently made by S.Teitel. He writes: "the insights derived from the analysis of technical change in terms of the market failure metaphor, while providing useful insights, are also not very helpful in the case of semi-industrialized countries since the role of uncertainty and externalities is quite different from that foreseen in the market failure mechanism"... "Although external effects may exist they are easily disregarded by private parties since the benefits...are enough to induce the necessary allocation of resources". In "Towards an understanding of technical change in semi-industrialized countries". Revised version of Working Paper N°34, IDB/ECLA/UNDP Research Programme on Science and Technology, Buenos Aires, April 1979.

"low understanding" to indicate lack of a reliable R and D activity; the phenomena here are very close and not readily separable in practice. Difficulties in imitation can stem from lack of explicitness about what is being imitated or lack of understanding to enable the imitator and teacher to distinguish essential from inessential elements; these aspects sound different but may be close to the same thing. However, I propose that for modeling purposes it is useful to think of three different dimensions in characterizing particular technologies: explicitness, imitability, degree of understanding. 7/

Whereas uncertainty, externalities, etc. provide sufficient ground to suspect market failure, Nelson's features -tacitness, inimitability and imperfect understanding- suggest that manufacturing firms will significantly differ among themselves, even when operating under roughly similar economic and market regime conditions. This is certainly a far cry from conventional production theory, and has an obvious consequence upon the "technology transfer" metaphor as we shall have the opportunity to see in future sections of this essay.

Having, looked at technical knowledge as a factor of production characterized by rather uncommon properties, we turn to a second topic of theoretical importance, i.e. the sources of new technical knowledge or information.

II.2 The search for new technical information

For many years the inflow of new technical knowledge was considered as exogenous to the economic system, as technical data concerning whose origin economists had nothing to say. Only recently has the profession began to admit the endogenous nature of technological events, i.e. the notion that the rate and nature of new technology incorporated by any given society is influenced by the general working of the economy. 8/

For economic theory to move in this direction it has been necessary a significant departure from conventional production theory. In his famous 1962 paper K. Arrow brought into the literature the idea of technical change having an endogenous character. In his view, firms accumulate experience pari pasu with their production activities, thus productivity goes up as a function of the accumulated level of output turned out through time. 'Experience' -which presumably means additional units of technical information- becomes a new asset which firms 'produce' jointly with their main output.

7/ R. Nelson, Op.cit.

8/ The beginning of the 1960s exhibits a dramatic change in this respect, as far as received literature is concerned. The NBER Conference on Innovation. See: (Ed. R. Nelson) The rate and direction of inventive activities, Princeton 1962; and K. Arrow's article of the same year. "On the economic implications of learning by doing". Review of Economic Studies, June 1962; constitute a turning point in this area of research.

From the point of view of empirical research Arrow's concept of 'learning by doing' soon found its way into econometric studies of the 'learning curve' as those carried out by W.Z. Hirsch, 9/ J. Hirshleifer, 10/ K. Hartley 11/ and others.

However, the 'learning by doing' concept or the 'learning curve' model contain nothing which would lead us to think that the firm has an explicit technological search strategy. There are no specific actions -R&D efforts, technological screening, copy and imitation of a third party's technology, etc.- which the firm needs to undertake in order to expand its stock of technical information. Moreover, there is no uncertainty, risk, or other such features proverbial of the knowledge creation field.

Shortly after Arrow's seminal paper, Ch. Kennedy first brought into the literature the notion of the Innovation Possibility Frontier (IPF) which grafically expresses the fact that ... "the entrepreneur will choose, or 'search for' the improvement that reduces his total unit cost in the greatest proportion" 12/ The idea of 'search' and the somewhat narrow view of technical change being only of the factor-saving variety, both come up quite clearly in Kennedy's paper which opened up a rather long debate in the profession. Such debate was more concerned with questions of income distribution and the stability of factor shares, than with the complexities of innovative behaviour.13/

9/ W.Z. Hirsch: Firm progress rations. Economêtrica, April 1963.

10/ H. Hirshleifer: The firm cost function, a successful reconstruction. Journal of Business, July 1962.

11/ K. Hartley: The learning curve and its application to the aircraft industry. Journal of Industrial Economics, March 1965.

12/ Ch. Kennedy. Induced bias in innovation and the theory of distribution. Economic Journal, September 1964.

13/ It all works back to Hick's famous contention in the Theory of Wages stating that a fall in the price of capital relative to labour would induce inventions of a labour-saving type. Op.cit. MacMillan, 1932 (pag.124). Such view was objected by the late W.E.G. Salter in his Productivity and Technical Change, (pag.43). Salter argues that: "If ... the theory implies that dearer labour stimulates the search for new knowledge aimed specifically at saving labour, then it is open to serious objection. The entrepreneur is interested in reducing costs in total not particular costs such as labour cost or capital cost. When labour costs rise any advance that reduces total cost is welcome and whether this is achieved through saving labour or capital is irrelevant". Op.cit. Cambridge University Press, 1960. As we can see the debate is concerned with the nature of technical change, and even this within the narrow boundaries of labour or capital saving innovations and their respective incidence upon relative factor shares in national income. Obviously there is much more than that involved in innovative behaviour. In spite of the rather colorful nature of the theoretical exchange we cannot fail to notice its very limited usefulness from the point of view of the new insights that such exchange permitted concerning the microeconomics of innovation.

The notion of the firm having a technological search strategy has remained in the literature even in spite of the fact that the IPF concept elicited strong criticisms on account of its mechanic and deterministic nature. 14/

The specification of search as a stochastic process, i.e. treating search efforts as drawing successive trials from a probability distribution of potential cost reduction innovations, has in recent years been employed by R. Evenson and G. Kislev, 15/ as well as by H. Binswagner 16/ in an attempt to provide further realism to neoclassical innovation theory.

Even though their models of the search process clearly represent a significant step forward, they still are based on a strong assumption, i.e. that the set of all possible searches is known by the firm along with the probability distribution of outcomes. As H. Binswagner has put it: ..."All derivations can be done as if we were dealing with a certainty model". 17/

The idea that firms search for technical information useful in production- which is a somewhat broader notion than searching within the space of factor -saving innovations- constitutes a central piece of other models of the inovation process which abdicate from the profit maximization assumption which underlies the neoclassical case.

March an Cyert, 18/ N. Rosenberg 19/ and others have suggested that search is 'problem-oriented', in the sense that it is stimulated by a particular symptom which in itself defines the neighborhood in which the search effort is conducted. In Rosenberg's words: "My primary point is that most mechanical productive processes throw off signals of a sort which are both compelling and fairly obvious. Indeed, these processes, when sufficiently complex and

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14/ W. Nordhaus pointed out some of the major theoretical difficulties which underlie the IPF concept. He concludes that "about the only microeconomic framework that preserves competition -a central assumption of neoclassical growth models- is one in which a book of new blue prints falls from the sky every period, and the entrepreneur chooses the best technique. In this case it would be rather misleading to say that technical change is induced". W.Nordhaus, "Some skeptical thoughts on the theory of Induced Innovations". Quarterly Journal of Economics, 1973, pag.209-19.

15/ R. Evenson and G. Kislev. Agricultural research and productivity,New Haven, Yale University, 1975.

16/ H. Binswagner: A microeconomic approach to induced innovation, Economic Journal, December, 1974, page 940.

17/ H. Binswagner, Op. Cit. pag.

18/ Cyert R.M. & March J.G., A behavioural theory of the firm. Englewoods Cliffs, Prentice Hall, 1963.

19/ N. Rosenberg: Perspectives on Technology, Cambridge University Press, 1976.

interdependent, involve an almost compulsive formulation of problems. These problems capture a large proportion of the time and energies of those engaged in the search for improved techniques". 20/

More recently Nelson and Winter advanced the interesting idea that many of these non-orthodox models -including their own 'evolutionary theory'-21/ are indeed consistent with the same qualitative comparative statics of conventional neoclassical analysis. "But explicit recognition of uncertainty, imperfect information, etc. as well as of the fact that real search processes take place in specific historical contexts"... "brings a whole new range of phenomena into theoretical view". 22/

Summarizing: as far as the sources of new technical knowledge is concerned we notice that the literature of the last two decades shows a clear trend from macro to micro aspects and from the exogenous to the endogenous nature of the forces that induce the generation of new technical knowledge. Deterministic and mechanic descriptions of technological search efforts are nowadays giving way to stochastic modeling of search behaviour. Production theory no longer confronts us with the rather simplistic "production-function story" - i.e. shifts as against movements along a given isoquant. Rather, it now exhibits a rich menu in which 'localized' 23/ technical changes can be found alongside with 'learning' phenomena and technological 'search' efforts. Uncertainty, trial and error and idiosyncratic patterns of behaviour are taken into consideration and examined in the research frontier of this field of enquiry.

As a consequence of these changes the microeconomic description of technological behaviour is becoming both more realistic and complex and, simultaneously, less amenable to a formal analitical treatment. In a very particular sense we can say that we have now entered in a pre-theoretical stage in which researchers are trying to develop new heuristics describing innovative behaviour before

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20/ N. Rosenberg, Op.cit., pag. 111.

21/ R. Nelson & S. Winter: In search of a useful theory of innovation. Research Policy 6, 1977, pag. 36.

22/ R. Nelson & S. Winter: Firm and industry response to changed market conditions: an evolutionary approach. Working Paper N°788, Institute for Social and Policy Studies, Yale University, New Haven, 1979, pag.23.

23/ The concept of 'localized' technical progress as opposed to a generalized shift of the overall production function has been examined by: J. Stiglitz and A.B. Atkinson: A new view of technological change. Economic Journal, 1969. Also P. David: Technical choice, innovation and economic growth, Cambridge University Press, 1975.

attempting further generalizations and model-building efforts. 24/

Many of the research results to be discussed in further Sections of this paper deal with choice of technique and with technological search efforts carried out by manufacturing enterprises in various semi-industrialized countries of the Latin American region. The rather peculiar structural features of LDCs -small domestic markets, high tariff protection, shortage of skills, etc.- and the imperfect understanding and partial inimitability of technological packages, both seem to be responsible for the fact that neither original choice of technique nor technological search efforts locally-undertaken by industrial firms, can be assumed to be a close replica of technological packages and of technological search efforts previously employed and undertaken by manufacturing firms in more developed industrial societies. We shall now proceed to examine choice of technique and the nature of technological search efforts in developing countries.

24/ A pathbreaking effort in this field is the one attempted by R.Nelson and S. Winter which are now beginning to test through simulation a rather long list of hypothesis concerning innovative behaviour and its relationship with market regime. See, for example: R. Nelson, S. Winter & H. Schuette "Technical change in an evolutionary model", W3-22, Yale University, July 1973. Also, from the first two of the above mentioned authors "Neoclassical vs. evolutionary theories of economic growth: critique and prospectus", W3-21, Yale University April 1973; "Factor price changes and factor substitution in an evolutionary model", The Bell Journal of Economics, Vol.6,N°2, Autumn 1975; "Simulation of Schumpeterian Competition", American Economic Review, Vol.67 N°1, February 1977.

III. LDCs, CHOICE OF TECHNIQUE AND DOMESTIC TECHNOLOGICAL SEARCH EFFORTS

The theoretical literature concerning technical change and innovation is mostly related to industrialized countries. Cost-reducing innovations, induced by strongly competitive market regimes, and 'major' breakthroughs associated to the dynamic expansion of the so called 'science-base' industries, constitute the normal background which underlies the work of researchers looking at these problems in DCs. There is no a priori reason on account of which their insights would prove useful to social scientists wanting to understand technological change and innovation in less developed societies.

On the one hand such societies are characterized by domestic markets which are smaller, and by rates of tariff protection which are much higher, than those tipically observed in developed countries. Business concentration tends to be higher 25/ 26/ and the competitive atmosphere weaker than those respectively prevailing in DCs. Moreover, acute market imperfections, distortions in technical information, shortage of skills, etc. are also rather frequent in LDCs.

The above mentioned features continuously flash out specific signals which induce local entrepreneurs to operate with highly idiosyncratic technologies and to carry out highly specific technological search efforts. Two aspects of technological behaviour in LDCs will concern us throughout this section, they are: a. choice of technique, and b. domestic technological efforts. In the next few pages we shall examine some of the more outstanding differences which in both such aspects prevail between DCs and LDCs.

III.1 Choice of technique

III.1.1 The incidence of market size

The first -and probably more important- difference between DCs and LDCs, and certainly one which greatly influences choice of technique is the size of the domestic market.

With very few exceptions industrial firms operating in LDCs are just a tiny fraction -between 1-10%- of the size of their counterparts in developed nations. For example, a 'representative' Latin American firm producing automobiles could turn up anything between 20 and 100 thousand units per annum. A machine tool manufacturer would produce from 100 to 500 lathes per year, whereas a petrochemical plant producing polyethylene would operate anywhere

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25/ The relationship between the degree of concentration, the rate of productivity growth and the rate of innovation has been explored by J.Stiglitz and P. Dasgupta, Op. cit. and they argue that both concentration and innovation were endogenous variables to the system.

26/ M. Merhar: Technological Dependence, Monopoly and Growth. Pergamon Press, London, 1969.

between 10 and 120 thousand tons per annum. 27/ Industrial firms producing similar commodities in mature industrial societies would normally be five to ten (or more) times larger.

Such differences in plant size induce very many differences in the technology with which products are actually produced. The present point has been recently made by S.A. Morley and G.W. Smith after studying a sample of Brazilian manufacturing firms, "When we looked closely at the way products are actually produced we could see why production methods may be insensitive to relative factor prices. It seems clear that economies of scale and technical considerations dominate technical choice almost regardless of factor prices". 28/

Continuous flow, highly automated technologies, which would normally be the technology of choice for a new industrial undertaking in a developed country environment, are frequently ruled out right from the beginning by firms operating in LDCs. This is so for at least two different reasons. On the one hand, such technologies normally envolve a rate of output which is well beyond the size of the local market. On the other hand, such plants frequently embody a level of operational and maintenance complexity which cannot be adequately handled by the locally available engineering and technical skills.

Instead of such option LDCs manufacturing firms usually settle for a discontinuous technology and for a much lower degree of automation, than those looked for by DCs firms. The choice of a discontinuous, not highly automated technology, certainly has a major impact upon such aspects as: 1. Plant 'lay-out', 2. Type, cost, etc. of the equipment and machinery to be installed, 3. Overall organization of production (degree and patterns of subcontracting, etc.) 4. Overall number of workers, 5. Proportion of direct to indirect labour, etc. Such choice will also affect the size of the economies of scale which can eventually be captured by the firm as well as the nature of the various technological search efforts that the manufacturing firm would find profitable to undertake through time.

In other words: not only will the physical configuration of the plant differ, but also the sources of efficiency growth (possibility for capital/labour substitution, economies of scale, possible forms of technical progress, etc.) will be dramatically at variance from those underlying the operation of a continuous flow, highly automated manufacturing unit. In order to make this point more explicit let us look at some of the main differences that prevail between a continuous and a discontinuous technology.

27/ Some recent interesting exceptions can be found among Brazilian firms, a few of which seem to be nowadays moving up in order to reach internationally competitive scales. This is, however, more the exception than the rule throughout the Latin American region.

28/ See: Samuel A. Morley and G.W. Smith: Adaptation by foreign firms to labour abundance in Brazil; in Technological progress in Latin America. The prospects of overcoming dependency. (Ed. J.H. Street and D.D.James), Westview Press, Boulder, Colorado, 1979.

Consider first the case of a continuous flow manufacturing plant.

Manufacturing plants employing a continuous technology are product-specific, i.e. their 'lay-out' is organized following a sequence imposed by the various technical transformations that have to be carried out for the purpose of producing a given product. The sequence of technical transformations is always the same and this is what decides the plant's 'lay-out'. In manufacturing units of this sort the rate of output is usually rather large. Continuous flow technologies are normally employed to produce massively commercialized products. Common features of a plant of this kind are:

1. The pre-production planning of the 'line' is extremely detail and complete. There is low ex-post flexibility concerning both product design and production process.

2. Activities and technical transformations sistematically follow one after the other along a 'direct' route, thus minimizing delays and waisted time. The production cycle is minimized ex ante, as the 'line' is balanced and activities have to be individually coordinated to the level of the micromovement.

3. Handling of raw materials and stocks of work in progress is also minimized. Inventories as well as storage spaces have to be balanced in conjunction with the overall production 'line'.

4. The product tends to be highly normalized and most of the equipment has a rather specific nature, i.e. is specially designed to fulfill particular tasks or combination of tasks.

5. There is relatively little 'on-the-job-decision-making', thus direct labour skills and supervisory requirements are relatively less important than in discontinuous production units.

In spite of its various potential advantages -in particular concerning economies of scale and minimum production cycle- a continuous flow production technology is not always and necessarily the cheapest available way of production. On the one hand, plants of this sort normally involve relatively large investment outlays. Unit capital costs tend to be rather large if the equipment is less than fully utilized. On the other hand, a stop anywhere along the 'line' can bring the whole of the line into a halt; thus, unplanned delays tend to be rather expensive. On account of both reasons a continuous flow technology can become far from economic in situations in which a steady rate of full capacity utilization is not guaranteed.

Plants 'embodying' a discontinuous technology are very different indeed. The plant's 'lay-out' is organized in 'shops' whose order is by no means unique, let alone constant through time. Such factories are frequently related to the production of goods or services in small runs or in response to individual orders. Various different products can be simultaneously produced, i.e. the plant is not designed following the array of technical transformations demanded by one specific product, but rather by 'groups' of somewhat similar machines or 'tasks'.

Frequent features of a manufacturing plant of this sort are some of the following:

1. The capital equipment is less expensive and of a more general nature than the one required by a continuous flow technology.

2. There is a great deal of flexibility in the way in which a given job is being performed. Given that all of the machines of a certain type can perform a particular task the actual work load is assigned to whatever machine happens to be available. Also, similar jobs can be performed with different machines.

3. Movements of raw materials, components, subassemblies, etc. between 'shops' becomes an important part of the production process. It is, also, a significant source of bottlenecks, waiting periods, etc. The production cycle is not minimized and there is ample room for actually reducing it by carefully re-arranging the physical distribution of jobs in the space.

4. Given that the product is not highly standardized, on-the-job-decision-making is relatively important. "Custom-ordered' changes are normally admitted. Workers skills in setting up the machines, preparing jigs and tools for the job, etc., and in actually carrying out the task, become very important indeed.

From both previous descriptions we notice that continuous and discontinuous technologies correspond indeed to very different 'production functions'. Given the limited size of the domestic market, manufacturing firms in LDCs frequently begin their operation on the basis of discontinuous 'batch-like' technologies, and of a relatively low level of automation. 29/ Thus, it can be hardly surprising to learn that very significant differences both in physical configuration and in modus operandi tend to prevail between industrial plants in DCs and LDCs. It is rather misleading to carry out straightforward productivity comparisons among production establishments of such difference.

Let us now turn to a second set of reasons on account of which firms in LDCs simply cannot replicate production techniques employed in more developed societies.

III.1.2. 'Roundaboutness'

The technology originally chosen by manufacturing firms in LDCs also differs from that employed by industrial enterprises in DCs in terms of the degree of vertical integration, i.e. the degree of 'roundaboutness' used in production.

29/ Discontinuous technologies have been employed many decades back by DCs. Current versions build up in LDCs constitute, however, rather idiosyncratic hibrids which maintain the basic discontinuous nature of the production process, but incorporate miriads of highly 'localized' improvements which the original version did not contain. In other words, it cannot be said that plants currently build up in LDCs simply constitute a replica of very old discontinuous designs employed decades back in DCs. Rather, they are highly idiosyncratic arrangements not previously used anywhere.

The empirical evidence as far as 'roundaboutness' is concerned shows that:

1. Manufacturing firms in LDCs make much less use of subcontracting than their counterparts in DCs. 30/

2. The degree of subcontracting seems to increase over time, but not at a very fast pace. 31/ Quite on the contrary, the time needed for the development of a reasonably efficient network of subcontractors in any particular branch of manufacturing seems to take the better part of two decades.

3. Subcontractors tend to grow out from the very fabric of large industrial firms. Case studies carried out in different metalmechanic and textile plants show that former technicians and workers of large firms frequently settle down as independent subcontractors, sometimes on the basis of second-hand equipment and technology obtained from the same company in which they acquired their original training. 32/

The slow pace at which the division of labour and the development of a sufficiently vast network of subcontractors seem to be proceeding in LDCs has, at least, two different explanations: size of the market and shortage of skills. The limited size of the market forecloses the likelihood of attaining efficient independent suppliers of parts, components, subassemblies, etc. A very low level of standardization and normalization further collaborates in the same direction.

30/ Besides A. Amsden's research results which illuminate this point in relation to the Taiwanese machine-tool industry -see her "The division of labour is limited by the type of market. The case of the Taiwanese machine tool industry". World Development, Vol.5, pag. 217, 1977- a similar pattern is suggested by H. Pack when he writes: "Despite efforts to foster subcontracting in the late 1960's the large Indian machine tool producer purchased only 10% of its inputs externally whereas for one Western European collaborator the comparable number was 40%. See: H. Pack: The capital goods sector in LDCs: a survey. Mimeo, April 1979, page 17. Identical results have been found in various of the studies carried out in Latin America. See for example: A. Castaño, J. Katz and F.Navajas, "Etapas históricas y conductas tecnológicas en una planta metalmecánica argentina". Mimeo, IDB/ECLA/UNDP Research Programme on Scientific and Technological Development in Latin America, Buenos Aires, 1980. See also: S. Watanabe, Technical cooperation between large and small firms in Philippine Automobile industry. World Employment Programme Research, ILO, Geneve, March 1979.

31/ Research now in progress in the metalmechanic industry of Argentina, Brazil, etc. indicates that the subject of subcontracting is only becoming an important one at the present time. See in this respect: A. Castaño, J. Katz, F. Navajas, Op.cit.

32/ See in this respect: a) A. Castaño, J. Katz, F. Navajas, Op.cit. and b) J. Katz et. al.: Productivity, technology and domestic efforts in research and development. Working Paper N°13, IDB/ECLA/UNDP Research Programme on Science and Technology, Buenos Aires, July 1978.

Size of the market is not however, the only impediment to the development of a network of subcontractors. Also, and most significant in countries in which a fairly large market already exists (such as Brazil or India) shortage of skills and entrepreneurship also appear as major determinants of the current state of affairs as far as subcontracting is concerned.

Whereas size of the market is related to the likelihood of attaining economies of scale and specialization, and therefore to the relative cost of external vs. internal production, the availability of technical skills and entrepreneurship is associated with quality standards and reliability, certainly two major aspects taken into account by large firms considering subcontracting decisions.

So much for the explanation of why subcontracting has thus far proceeded at a rather slow pace throughout the Latin American region. Besides explaning why this has been so, it is also worth looking at some of the consequences.

A high degree of vertical integration normally means 'inhouse' provision of goods or services which are technologically dissimilar to the company's major activity (e.g. a metalmechanic plant having to produce rubber or plastic components, which demand a rather different set of scientific, engineering and production principles than those which are demanded for the production of metalmechanic products). A high degree of technological dissimilarity necessarily means lower technical specialization, and many more difficulties concerning production planning and industrial organization. Equipment subutilization is to be expected in situations in which firms are forced, by lack of subcontractors, to overextend their degree of vertical integration. 33/

Summarizing: two major reasons force large manufacturing firms in LDCs to operate on the basis of a higher degree of vertical integration than the one normally chosen by comparable firms in DCs. 34/ Such reasons are the limited size of the domestic market and shortages in the supply of engineering and entrepreneurial skills. On account of both such reasons manufacturing firms in LDCs are normally forced to settle for a manufacturing and an organizational technology which significantly differ from those employed by comparable firms in DCs. Highly idiosyncratic technological packages normally result from the particular economic environment in which firms find themselves operating.

We turn now to a third set of reasons on account of which production techniques are likely to differ in a significant way between DCs and LDCs.

33/ Recent interesting examinations of the problem of subcontracting can be found in: a) H. Pack: Op. cit.; and b) S. Lall: Linkages revisited. Mimeo, Oxford University, 1980.

34/ For a similar conclusion see: A. Amsden: Op. cit., also S. Watanabe: Op. Cit.

III.1.3 Substitution effects

Various substitution effects play an active role inducing firms in LDCs to adopt different production techniques than those normally employed by comparable firms in more developed countries. Substitution effects could be policy-induced or 'autonomous', i.e. derive from differences in resource endowments or other such 'natural' sources.

Under the heading of 'policy-induced' substitution effects we include all those forms of substitution between different types of machinery and/or raw materials, etc. -particularly among those of a local vis a vis imported origin- which result from tariffs on imported goods, quotas, distorted exchange rates, outright prohibition of access to certain inputs, etc. all of which have been shown seriously to affect choice of technique among Latin American industrial firms. 35/

As far as 'autonomous' factor substitution is concerned relative price differentials as between capital and labour induce important technological differences between firms in LDCs and DCs that need to be mentioned at this point. A much lower degree of automation -implying more universal machines or manual rather than electronic process control devices, a less sophisticated maintenance technology, a more labour intensive transportation system within the plant, etc. are all standard features of the Latin American manufacturing scenario. This is particularly so when we look at the original choice of technology, i.e. the technological package with which most of the companies examined during the course of this research programme originally started to

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35/ See in this respect: a) A. Canitrot: Method for evaluating the significance of macro-economic variables in the analysis of technology incorporation decisions. Working Paper N°12, IDB/ECLA/UNDP Research Programme on Science and Technology, July 1978; b) S. Teitel: Notes on technical change induced under conditions of protection, distortions and rationing. Working Paper N°34, IDB/ECLA/UNDP Research Programme on Science and Technology, April 1979; various case studies of the IDB/ECLA/UNDP Programme present empirical evidence confirming the fact that choice of technique reflects factor price differentials as between countries. Among such studies: 1) J. Fidel & J. Lucângeli: Cost-benefit of different technological options in the context of a differentiated oligopoly: the case of the Argentine cigarette industry. Working Paper N°18, IDB/ECLA/UNDP Research Programme on Science and Technology, October 1978; 2) R. Pearson: Technology, innovation and transfer of technology in the cement industry. Working Paper N°9, IDB/ECLA/UNDP Research Programme on Science and Technology, December 1976; 3) F. Sercovich: Design engineering and endogenous technical change. A Microeconomic approach based on the experience of the Argentine chemical and petrochemical industries. Working Paper N°19, IDB/ECLA/UNDP Research Programme on Science and Technology, October 1978.

operate. 36/ At their starting point almost all of the firms we have examined began with a rather high ratio of labour to capital. In due course, however, most of them, as well as newly arriving competitors in the same industries, opted for more capital intensive technologies. 37/

We can now close the present section by briefly re-stating its central point. Size, lack of subcontractors, policy-induced and autonomous substitution effects, etc. on the one hand, and, on the other, the essential inimitability and incomplete understanding and irreplicability of technical information all seem to play a role in making DCs technological packages -i.e. product designs, production processes and patterns of industrial organization- different from those employed by industrial firms in LDCs. The latter ones normally choose highly idiosyncratic technologies which reflect the nature and intensity of local market imperfections, prevailing physical scarcities, factor price differentials, degree of development of the network of subcontractors, size of the domestic market, etc. Rather than assuming that firms tend to use identical techniques across countries it becomes all the more urgent to accept the idiosyncratic nature of the technology employed by firms in LDCs and explore the impact of such differences upon productivity differentials.

Having looked at choice of technique, let us now turn to the 'production function' for new technical knowledge and information.

III.2 The search for new technical knowledge

III.2.1 'In-house' engineering activities

Given that production functions significantly differ across firms, the introduction of changes in the engineering routine of any given plant will normally involve a certain amount of 'custom-ordered' specificity. This being so there is reason to expect industrial firms to undertake technological search activities with the purpose of generating incremental units of technical information useful within the plant.

36/ Most of the case studies in the Programme indicate that local firms normally started their operation with labour-intensive 'in-plant' transportation systems as well as with labour-intensive control and maintenance technologies. Many of these firms moved during the course of time into more automated versions of such technologies. Higher wages and a much higher volume of output both seem to be responsible for such move.

37/ An interesting case at point can be seen in J. Katz et.al., Op.cit. In this study the newly arriving firms, getting to the market some 15 years after the initial plant, brought in a more automated technology than the one operated by the original firm. This last one was then forced into a drastic plant modernization programme which made unnecessary close to one third of the labour force employed by the plant.

In this section of the paper we examine such knowledge-generation process. We would try to answer questions such as: a) Which departments or activities in the firm have as their major task that of 'producing' new technical information? b) How is the size and nature of the firm's technological search effort influenced by company-specific and by market and macroeconomic forces? etc.

Consider first the question of knowledge-generating activities performed at the individual firm level. Three different categories of engineering and technical activities can be identified which 'produce' a steady flow of new technical knowledge or information. They are: 1. Product Engineering, 2. Production Process Engineering and 3. Industrial Organization and Production Planning.

It should be noted that such technical activities might or might not be performed by formally organized departments or sections within the firm. The same technical functions will be present even if a formal structure is absent. They are carried out by the entrepreneur himself in small family enterprises and are gradually decentralized and covered by specialized personnel when the firm acquires larger size and complexity. It is the nature of such technical activities what we want to examine in the next few pages.

In dealing with 'in plant' knowledge generation activities the differentiation between continuous and discontinuous production processes becomes once again very important. Significant differences prevail among them in terms of stability of product design, flexibility of the production process and industrial organization of production at large. Such differences strongly affect the nature of the 'in-house' technological search efforts, as we shall proximately notice.

Let us begin by considering each of the previously identified technical functions.

a. Product design and specification

Being responsible for answering the question of what to produce the Product Design Department -or the design function, whenever a formal department is not organized within the firm- constitutes the very first technical activity that needs to be fulfilled by any given enterprise. The Product Design Department employs different design techniques, construction of prototypes, pilot plant experimentation, etc.- with the aim of attaining a final product design which minimizes engineering complexity, input content, etc. for a given performance.

The engineering knowledge generated by this department takes the form of 'blue-prints', formulaes, etc. specifying different aspects of the product to be produced. Also, this technical department has the responsibility of producing incremental units of technical information on the basis of which to upgrade, improve or modify the currently available product design.

Economic, as well as technical considerations, influence the technological search efforts carried out by design personnel. On the one side, product differentiation 'output-stretching' and/or cost-reduction needs imposed by competitive pressure can be frequently traced back as motivating forces behind the activities of product design personnel. On the other hand, new technical information -coming up either from Service statistics, trade journals, academic publications, and so forth- could point out towards the need of re-designing specific parts and components and/or of producing them with different raw materials or under different physical conditions. Typical of the technical search efforts carried out by product design engineers are: a. product simplification studies; b. standardization and normalization of parts and components; c. substitution between raw materials, etc. Many of these technical efforts involve a great deal of interaction between product design personnel and members of the process engineering and industrial organization departments.

b. Process engineering

The process engineering section of the firm is responsible for answering questions such as how, by whom, where, should the product be produced. For such purpose it has to select the equipment and the labour force -size and skills of the crew- as well as the type of raw materials, components, etc. to be used in production.

It also has to work out detail instruction sheets indicating the engineering routines to be followed, tolerance limits, etc.

It is this group within the plant the one that will explore all potential 'output-stretching' capabilities embodied in the existing equipment, 38/ as well as the behaviour of alternative raw materials in the production process. 39/ Pilot plant experimental work as well as time and motion and job evaluation studies constitute some of the technological search efforts normally carried out by this engineering department. There is a great deal of cummulative learning underlying the activities of this office as it has to acquire capabilities for registering and interpreting technical information describing the behaviour of the production process under different working conditions. The acquisition of such capabilities involves a very major step in terms of organizational structure, use of electronic equipment for the collection and processing of information, etc.

c. Industrial engineering: planning and control of the overall production operation.

A third technical department with a major role on technical affairs is the one responsible for planning and control of the overall production operation. This technical section of the plant -normally called Industrial Engineering Department- is the one that has to issue a formal production plan stating when

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38/ See P. Maxwell: Implicit R&D strategy and investment-linked R&D. A study of the R&D Programme of the Argentine steel firm, Acindar S.A. Working Paper N°23 IDB/ECLA/UNDP Research Programme on Science and Technology, March 1979. Also: F. Sercovich, Op.cit.

39/ A large proportion of the technological search effort carried by the process engineering departments of the individual firms examined during our field work was found to be related to the need of substituting one raw material for another. A change in tariffs, or the need for reducing the uncertainty involved in external supplies, were found as frequent inducements behind these search efforts.

each action should be performed, in which machine or equipment using what externally acquired part and components, etc.

Also, it is the Industrial Engineering personnel the one that decides on size of 'batch', machine-loading programme, degree and patterns of external subcontracting, level of inventories, etc. Moreover, it is also this technical office the one that has to integrate into the overall operative network the functions of plant maintenance, raw materials purchasing, quality control, etc.

Given the central role fulfilled by the Planning and Control Department it has a rather large scope for introducing changes in the engineering routine followed by the plant.

In actual facts such department operates on the basis of a long term plan, a short term action programme and a control function which monitors whether or not the current operation is proceeding as expected.

Contrary to the other two technical sections which have very precise knowledge-generating activities whose output can be explicitely identified as a set of 'blue-prints', production manuals, etc. the Planning and Control Department has a less obvious knowledge-generating function but, nonetheless, an important one. It is this section the one that has to issue -on a daily, weekly, etc. basis- the production plan of the firm. Far from performing a static allocative exercise this section fulfills a dynamic role, constantly adjusting the plant's operation to the changing signals emerging from the market place.

The role as well as the <u>modus operandi</u> of the three previously-described technical departments is rather different in continuous and discontinuous, manufacturing plants. A fortriori such technical departments will behave differently in manufacturing plants operating in DCs and LDCs.

In the case of an homogeneous commodity produced in a continuous 'line' -as it is the case with the production of automobiles, petrochemical products, etc.- we have a rather inflexible product design as well as a tightly specified production process. None of them can be significantly modified. The pre-production engineering efforts, related to both product design and process engineering are very specific and so is the overall planning of the plant's operation. A great deal of 'ex ante' technical work is put into balancing the production line. Time and motion studies are required for such purpose, and such studies come right down to the level of the micro-movement. Given such a degree of pre-specification of the production routine the amount of ex ante technical information that has to be prepared for each position in the 'line' is rather large. Time and motion specialist, programmers, and other such skilled personnel are employed in order to describe the package of technical information required for each subactivity.

Contrary to such picture in discontinuous plants production planning is done almost every other time a given product is produced. There is significant scope for reducing the duration of the production cycle which is now highly dependent on the amount of time which is employed in 'transport' operations as well as waiting in between 'isles'. Size of 'batch' becomes now a crucial determinant of economies of scale. Technological search efforts addressed at identifying 'families' of parts and components, are carried out with the purpose of increasing the size of 'batch' once certain similarities among parts and components can be established. A larger batch means lower preparation time per unit and, therefore, economies of scale in production.

Keeping in mind the dichotomy between continuous and discontinuous technologies let us take a look to the previously-described 'in-house' knowledge-generating activities. It can be intuitively perceived that the three previously described technical departments will have different responsabilities and will fulfill different roles in plants of one or other type.

In the case of a continuous flow plant product design 'blue-prints' as well as production routines are available on an ex ante basis. Almost each and every other part, component, or production subroutine is treated with equal care. Both, product design and process engineering efforts are crucially different in discontinuous process plants. Following what engineers call the 'ABC method' careful attempts are made at designing some 20-30% of the total number of parts and components which conform a given product design, leaving the remaining 70-80% of the total list relatively less attended. 40/

Thus, in a discontinuous plant there is a lot more of 'ad hoc' decision making done at the shop level and therefore skill requirements for machine operators are significantly greater than those tipically demanded by a continuous flow plant. Skillful craftmen , with decades of experience in the actual technical secrets of each particular job, substitute for job programmers and time and motion specialists.

Also, the Industrial Engineering Department of continuous and discontinuous plants fulfills a different role. In the latter case such office is responsible for issuing a Machine Loading Programme the purpose of which is that of minimizing waiting periods as between jobs and capacity underutilization emerging from imbalances as between stations. By definition of continuous flow the production 'line' is balanced ex ante, the production cycle is minimized as from the begining, and no Machine Loading Programme needs to be issued at all.

Before closing the present section let us briefly mention the high degree of interdependence that prevails between the previously described technical departments.

40/ Parts and components of a given product design, as well as the respective production routines, are classified according to their relative weight in total cost. It is then observed that only a small proportion -usually less than 20% of the total list- accounts for close to 80% of total cost. Those items are classified as 'Category A' and are the ones that receive the most attention as far as design and production methods are concerned. There is a second 'Category B' some of whose items, but not all of them, receive individual attention from the product design and process engineering teams. The remaining items, -a rather large number, but accounting only for a minute fraction of total cost- is called 'Category C'. Standard versions of them available in the market -nuts, bolts, screws, etc.- or rather unsophisticated 'in-house' designs, are employed in this case. See: Introducción al estudio del trabajo, ILO, Geneve 1966. Also: Tools and manufacturing engineers handbook, Mc Graw Hill Book Co., USA, 1949.

In most real life situations the design of a given product, the substitution of one raw material for another, etc. is far from independent from the way in which the product is produced. An viceversa, various physical parameters of the production process, e.g. speed and others are strongly correlated with the product's quality, reliability and general performance. Thus, it is frequently observed that 'in-house' knowledge-generating efforts demand mixed groups in which product design engineers, personnel from the Process Engineering Department, and members of the Production Planning Office interact with one another rather strongly. Normally, one of the three departments leads the search operation -which one depending on whether the search entails a new product, a new production method or a change in the organization of production- but there seems to be consensus around the idea that successful technological search efforts usually involve a combined action from all three technical offices.

Having answered the first of the previously stated questions, i.e. which activities 'produce' new technical information at the individual firm level we turn now to examine the available empirical evidence concerning the rate and nature of technological search efforts undertaken by different firms and industries in the Latin American region.

III.2.2 Rate and nature of the domestic technological search efforts.

As far as statistical information is concerned studies carried out in Argentina, Brazil, Mexico, Colombia, etc. give a preliminary view of the current situation.

Two micro enquiries performed in the Argentine manufacturing sector show R&D expenditure which, towards the end of the 1960s, were in the order of 30 U$S millions annually. 41/ On average this represents between 0.3-0.4% of the value of output of the industrial firms included in the surveys. 42/

R&D figures seem to be marginally higher in the pharmaceutical sector and in the electronics industry. 43/

41/ These studies are: J. Katz, *Op.cit.*, Fondo de Cultura, Mexico, 1976. Also by the same author: The creation of technology in the Argentine manufacturing sector. *Working Paper N°1*, IDB/ECLA/UNDP Research Programme on Science and Technology, Buenos Aires, August 1978. INTI (Instituto Nacional de Tecnología Industrial): *Aspectos económicos de la importación de tecnología en la Argentina*, Buenos Aires, November 1974.

42/ In both studies the unit of analysis was the 200 largest industrial establishments in the country, which on aggregate accounted for nearly 40% of manufacturing product in the middle 1960s.

43/ The information can be found in J. Katz, *Op.cit.*, Fondo de Cultura, Mexico 1976. Various Argentine pharmaceutical firms show technological expenditure ranging from 1 to 2% of their annual sales. See: J. Katz: *Oligopolio, firmas nacionales y empresas multinacionales*, Siglo XXI, Buenos Aires, 1974.

Mexican 44/, Brazilian 45/, and Colombian 46/ figures tend to confirm such picture, whereas all of the individual firm and industry studies carried out within the framework of the IDB/ECLA/UNDP Research Programme on Science and Technology in Latin America indicate that large industrial enterprises in the region carry out technological search efforts of one sort or another through their product design, process engineering or industrial organization departments. Expenditure in the region of 200-300 thousand US dollars per firm per annum, the use of pilot plant facilities and prototypes and the employment of anything between ten and fifty (or more) engineers and technicians for activities of this kind are by no means unusual in the regional industrial scenario described by the case studies.

New questions derive from such empirical evidence.

First: what kind of technological search activities are locally carried out by industrial firms? Second: what is the influence of micro and macroeconomic forces upon entrepreneurs' behaviour in this field? etc. Let us look at such questions.

A. Nature of the domestic technological search efforts.

As we have seen in Section I most of the literature on technological change and innovation emerging from DCs deals extensively, and sometimes exclusively, with cost-reducing innovations. In one of the more detailed empirical plant studies so far available, S. Hollander has written: ..."We shall call technological change any modification in the production technique of a given product, put in practice by a given specific plant, with the aim of reducing its unit production cost". 47/ Hollander's view is consistent with a long standing tradition among DC economists.

In his well known book W.E.G. Salter defined the rate of technological progress in the same way. He wrote: ... "the degree of technological progress from one period to another is defined and measured as the relative change in total unit costs, assuming that the technique used in each period is that which minimizes these unit costs". 48/

44/ M.S. Wionczek et.al., La transferencia internacional de tecnología- El caso de México. Fondo de Cultura Económica, México 1974.

45/ II PBDCT - II Plano bâsico de desenvolvimento científico e tecnológico Centro de Serviços Gráficos do IBGE, Río de Janeiro, Brazil, March 1976.

46/ M. Ramírez Gómez, D. Sandoval. Tecnología en el sector manufacturero colombiano. Working Paper N°22, IDB/ECLA/UNDP Research Programme on Science and Technology, Buenos Aires, October 1978.

47/ S. Hollander: The sources of increased efficiency. A study of Dupont rayon plants, MIT University Press, Cambridge, 1965, p.23.

48/ W.E.G. Salter: Op.Cit.p. 23.

It is apparent from the previous quotes that the literature emerging from DCs deals almost exclusively with cost-reducing innovations and simultaneously tends to ignore other possible effects of technological search efforts such as quality improvements, diversification of the output-mix, replacement of imported raw materials and spareparts by local substitutes, 49/ etc.

Several of the studies carried out within the framework of the Science and Technology Research Programme reveal that cost reduction was not necessarily a priority of the technological search efforts undertaken by Latin American firms. Quite on the contrary, product mix diversification, quality 50/ and the more effective use of installed capacity 51/ normally appear as important objectives of the technological search efforts. Such non-conventional behaviour can probably be explained by market regimes in which high external protection and a very low degree of internal competition have prevailed for rather long periods of time.

Summarizing: with regards to the kind of technological search efforts performed by Latin American firms the available evidence suggests that such efforts respond to a variety of objectives, among which that of lowering production costs is only one, and not necessarily the most important one. In a less competitive environment than the one prevailing in developed countries, the search for cost reductions may well be less important than other alternative strategies. Thus, the technological path followed by manufacturing firms in LDCs will most likely differ in a rather substantive way from the one described in

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49/ Even though substituting one imported raw material for a domestically produced one (not always the exact equivalent) may well not have a direct effect on costs -or may even exercise a negative effect- this does not prevent such a substitution from normally demanding a significant technological effort to be put into operation. Looking exclusively at costs can make us lose sight of this point.

50/ The paper by Fidel, Lucángeli and Shepherd relating to the cigarette industry and Vitelli's research on the construction sector show how the launching of new products is the main objective of the technological activity of firms in these sectors. In both cases the aim of reducing production costs is rather unimportant. See: a) J. Fidel, J. Lucángeli and P. Shepherd: The Argentine Cigarette Industry: Technological profile and behaviour. Working Paper N°7, IDB/ECLA/UNDP Research Programme on Science and Technology, Buenos Aires, September 1978; b) G. Vitelli: Competition, oligopoly and technological change in the construction industry. The Argentine case. Working Paper N°3, IDB/ECLA/UNDP Research Programme on Science and Technology, Buenos Aires, August 1978.

51/ The previously cited study on the Argentine rayon industry shows that during the period 1937-1950 when Ducilo held a monopolistic position in the domestic rayon market, its technological strategy consisted of searching for a higher spinning speed in order to produce more output with the available equipment. During this stage there was little "technological search" aimed at reducing costs. However, the latter became the nub of technological strategy during the sixties and seventies when the market became more competitive with the entry of Sniafa and Reysol. See: J. Katz et.al., Op.cit.

simplification; 2. standardization of production methods; 3. Dissemination of technical information, both among producers and consumers, etc.

It is precisely the fact that such dissemination of technical information takes place what explains that in a fair number of cases -which range form foodstuffs and textiles to agricultural and transport equipment- succesful local immitations could be arrived at by skillful craftmen or technicians. 53/ Licensing and product design transfers within the framework of MNCs constitute the other major mechanisms through which access is being obtained to the original product designs which conform the starting point of the industrialization process of most of the Latin American manufacturing markets.

Technological search efforts in the area of product design seem to appear rather early in the technical history of many of the examined manufacturing firms. Only a few years after start up firms seem to begin developing 'in house' technical skills related to product engineering. On the basis of such skills they, first, adapt and improve the original design and, second, start playing product differentiation strategies as part of their competitive behaviour. The 'life-cycle' of industrial products as well as the relatively low incentive to search for cost reduction innovations, given the rather extreme degree of protection granted to industrial firms, appear as major explanations of the fact that product design engineering capabilities seem to develop at a somewhat earlier stage. We have observed that firms begin with such search efforts much before they can exhibit significant technical strength in other technological areas. Prototypes and plant experimentation for product design purposes seem to appear on the stage way before time and motion studies or other such tools of production engineering are employed by 'in house' technical personnel.

The previous statement should not be taken to mean that technological search in areas related to process engineering are entirely absent during the initial years of firm's life. Rudimentary forms of search are almost invariable present during the 'start-up' period. 54/ Also, substitution of one raw material for another, the introduction of new or improved products, etc. are activities which necessarily call for some limited amount of search concerning both the production process and the organization of production.

A certain discontinuity could be uncovered in the technical history of most of the firms examined by the present research Programme. Such discontinuity has frequently envolved a major change of attitude concerning process engineering and production planning and was associated to a new approach towards questions of

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53/ A large number of locally-designed products can be identified in the Latin American manufacturing escenario. The ingenious combination of available separate pieces of technology frequently constitutes the basis of an indigenous technological design. For example, a horse-powered harvest machine and the power plant of a passangers vehicle provide fertile soil for an imaginative local mechanic to design a complex agricultural machinery. Creative sequences of such sort, based on the assembly of already available pieces of technology, are rather frequently found in the largest Latin American countries.

54/ M.E. Clark, E.M. de Forest and L.R. Stechely. Aches and pains of plant 'start-up'. Chemical and engineering progress, Vol.67, December 1971.

quality control, limits of tolerance, preventive maintenance, and other such technical matters. In many cases such change of attitude was related, both to a significant re-organization of the firm's administrative structure (with the creation of a number of new departments such as Quality Control, Research and Development, Tooling, etc.) and, to a major increase in the size and complexity of the firm's output mix. Both such changes called for a rather different way of handling Inventories, Machine Loading Programmes, Quality Control, transport operations within the plant, etc. Process engineering and organizational skills generated in an informal way during the initial years of company operation were found to be insufficient at that point, this flagging the need for a radical change in organizational structure, in data gathering and interpretation efforts, etc. A new approach towards engineering efforts frequently obtained after such discontinuity, being noticeable a drastic change in the ratio of indirect to direct labour inputs.

As much as individual firms have been argued to undergo changes through time both in organizational structure and in the rate and nature of the technological search efforts they commit themselves to, also markets seem to experiment significant changes in structure and in competitive atmosphere. Two 'stylized' cases seem to stand out from the various case studies undertaken in Latin America. In both cases market structure and the competitive climate significantly changed through time inducing subsequent changes in technological search efforts. In 'case I', due to the granting of an exclusive import license, or to the early entrance of a large enough plant capable of catering for all (or most) of the domestic market, the prevailing market structure at the industry's starting point was found to be that of a monopoly. Automobiles, the production of some chemical and petrochemical products, etc. tend to reflect a situation of this sort.

On the other hand, 'case II' describes an entirely opposite market structure, i.e. one whose starting point is characterized by the existence of many small undifferentiated competitors. Such situation prevailed in different branches of the Metal-mechanic sector 55/, in residential construction 56/, etc.

Both cases were observed to evolve through time into situations of an oligopolistic nature. The case of the protected monopolistic did so as a consequence of new entry induced by abnormally high profits. 57/ The other one is somewhat more complex. We have noted that either a financial and/or a technological advantage permitted one of the firms eventually to outgrow its competitors, raising its market share and finally becoming a market leader.

Technological search efforts are clearly influenced, both, in their rate and in their nature, by the dynamics of the market's competitive atmosphere. Monopolistic situations has been seen to be relatively more associated to technological search efforts of the 'output-stretching' variety than to cost-reducing and/or

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55/ See: A. Castaño, J. Katz & F. Navajas, Op.Cit.

56/ See: G. Vitelli, Op.Cit.

57/ A model of this sort has been recently presented by R. Nelson and S. Winter in: The Schumpeterian trade off revisited . Working paper N°834. Institution for Social and Policy Studies, New Haven, May 1980, Mimeo.

quality improvement innovations. By the time the monopolistic advantage evolves into an oligopolistic confrontation, product-differentiation search efforts, as well as a stronger interest for cost-reducing innovations are likely to develop as well. Contrarywise, other things being equal, more competitive environments have been observed to lead to cost-reducing technological search efforts as well as to product-differentiation strategies.

Summarizing: our studies suggest that: a) product design efforts tend to develop rather early in company history only to be followed at a later stage by process engineering and production planning activities. b) More competitive environments seem to induce a stronger drive in the direction of product differentiation and cost reducing search efforts. c) On the contrary, monopolistic market situations seem to induce search efforts of the output-stretching variety rather than quality improvements and/or product differentiation.

Obviously we should not take the above-mentioned 'trends' in a restrictive way, as indicating that always, and as a matter of logical necessity, firms behave as hereby suggested. Similarly, there is nothing compulsory leading monopolistic firms into output-stretching innovations and more competitive ones into product differentiation efforts. Cases can be found where such 'tendencies' do not obtain, and yet our generalization seems to be supported by various different individual case studies.

We have thus far looked at the role of micro and market-specific variables in inducing specific technological search efforts from the part of manufacturing firms in LDCs.

It can be scarcely surprising to know that firms also react to changes in macroeconomic parameters by modifying their behaviour. Magnitude of the change and company's degree of perception seem to be rather crucial determinants of the pattern of reaction. 58/

The following relationships have been observed to prevail:

a. An increase in the cost of capital equipment -which obtains, for example, as a consequence of a higher rate of interest and/or of a currency devaluation, etc. induces entrepreneurs to postpone major investment decisions. Simultaneously, the advantages of output-stretching technological search efforts are enhanced.

Conversely, subsidies to capital expenditure -such as, for example, those that emerge from a cut in taxation, or from the granting of an import license at a preferential exchange rate- increase the internal rate of return of a given investment project, thus enhancing the likelihood of the firm modernizing its plant on the basis of new equipment. Socially unjustifiable overextensions of the life cycle of outmoded plants, as well as equally unjustifiable anticipated plant

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58/ H. Schwartz, from the IDB, has recently examined the subject of perception coming up with a very stimulating monograph on a topic which has thus far been given much too little attention by economists. See: Perception, judgement and motivation in decision making. Hypothesis suggested by a study of metalworking enterprises in Argentina, Mexico and the United States. (Mimeo), Washington, November, 1979.

scrap decisions have both been detected during the course of our field work. 59/

b. A rapid rate of demand expansion -resulting for example, from different policy actions related to aggregate demand management- will most probably induce favourable expectations among entrepreneurs and therefore induce optimistic investment programmes. Such expantionary business 'climate' will reduce the likelihood of search efforts of the output-stretching variety, making it more probable the erection of new production facilities.

c. The rate of interest -in as much as it represents the cost of time- also has a rather strong influence upon technological behaviour. An increase in the rate of interest, other things being equal, can be expected to induce search efforts directed towards the reduction of the production cycle. Such efforts could be of the product engineering sort -simplification of design standardization, etc.- but will also probably entail process engineering aspects, (for example: reduction of transport operations in between 'stations' of a discontinuous process plant) or production planning questions (such as, say, a more adequate management of inventories of raw materials and components). 60/

d. Tariffs also seem to play a role in determining the direction of search followed be a given company. Sheltered from external competition local firms feel some what less compelled to improve their product's quality. Obviously there is still some incentive coming from domestic competition but this one is not necessarily a perfect substitute for the former. Output-stretching innovations are more likely to obtain in such market regime than product-improvements.

e. Other features of the macro-economy -besides tariffs, the rate of interest, the rate of expansion of G.D.P., the level of taxation, subsidies to capital expenditure, etc.- will also influence micro-economic technological behaviour. Two conditioning forces of major importance should be mentioned at this point. First, availability and cost of skilled personnel, including here long term macroeconomic efforts in education, training, etc. of the labour force. Second, all those measures of direct support to individual company's research efforts, such as tax incentives to R&D expenditure, direct public participation (through universities, public research laboratories, etc.) in technology

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59/ See: J. Fidel & J. Lucángeli, Op.cit.1978 and A. Canitrot, Op.cit. 1978. Also P. Maxwell, First-Best technological strategy in an "Nth-best" economic context. A case study of the evolution of the Acindar steelplant in Rosario, Argentina. Working Paper N°16, IDB/ECLA/UNDP Research Programme on Science and Technology, Buenos Aires, April 1978.

60/ After experiencing for large decades a negative rate of interest the Argentine economy has in recent years passed to a regime of a rather high and positive value of such variable. Various different firms under study carried out search efforts of the sort indicated in the text, being it noticeable that the production cycle could be reduced by as much as 30% in some cases.

generation programmes, etc. 61/ A final set of forces influencing firms' technological behaviour is related to events of a scientific and technological nature taking place at the knowledge frontier. Let us briefly examine it.

It is frequent in the field of technology to hear about the existence of 'science-based' industries which are defined as those in which ..."latent productivity evolves over time at a rate determined by outside forces (i.e. advances in fundamental physics or biology, etc. resulting from research at universities)". 62/ 63/

Both, the rythm of expansion of the 'best practice' frontier and the ease of imitation of the evolving technology, are crucial aspects of the competitive atmosphere prevailing in such industries. There seems to be consensus in the literature concerning the fact that 'science-based' industries are characterized by rather elastic demand functions, and by a product design and a production process which are both relatively flexible and therefore admit quite significant ad-hoc changes. Product engineering efforts are of fundamental importance particularly so during the initial stages of product development and market testing. Process engineering and production planning efforts also tend to be important, as the experience seems to indicate that frequent changes have to be introduced both in the equipment -which is of a more universal nature- and in the organization of production.

Given their rather high content of engineering inputs per unit of output 'science-based' industries seem to be far from accessible for LDCs firms. Quite on the contrary, innumerable branches of manufacturing exhibit a much slower technological pace, conformed by cummulative improvements around a basically stable technological paradigm. The likelihood of LDCs firms 'catching up' with average international practices is considerably greater in these industries than in the former ones.

'In-house' technology generation activities will no doubt reflect in various different ways the evolution of the 'knowledge frontier' underlying the activities of any given firm. An interesting example emerging out of the case studies of

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61/ Almost every other government -both of the developed and less developed world- is presently involved in heavy subsidization of R&D expenditure. The decision of interfering in the 'knowledge' market is a clear reflexion of the fact that market forces can not be expected to induce an adequate allocation of resources to the creation of new technology.

62/ R. Nelson & S. Winter: Op. cit., 1980.

63/ There is a certain 'cross-fertilization' effect which needs to be mentioned at this point and which comes from the recent dramatic expansion of the electronic industry. Microprocessors and electronic process control equipment of all sorts are presently being adopted with great success by sectors as different as Foodstuffs or Textiles, thus making it possible for some of the advances in one of the 'science-based' sectors to penetrate into the production fabric of 'non-science-based' industries. Effects of this sort can also be found in other areas of manufacturing.

the present Research Programme is that of metalmechanic firms producing, say, machine tools, which have been forced to introduce changes in the skill composition of their product design and process engineering departments in order to 'catch-up' with the rapidly evolving trend into electronically-controlled machine tools which seems now to be on the making at the world-wide level. Other examples of this sort -envolving the use of electronic monitoring technology- were found in steel and petrochemical plants. 64/

Summarizing:

An 'evolutionary' sequence seems to obtain as far as in-house knowledge generation efforts is concerned. Such sequence involves search, and learning, in a much more fundamental way than the one presently contained in the received theory. Product design capabilities, followed by process engineering and production planning skills, seem to develop in a sequential order, absorbing the best part of one (or even two) decades of company technical history.

The market's competitive atmosphere, the changing package of macroeconomic parameters and the exogenously-given advances of the knowledge frontier, will permanently flash out specific technical and economic signals inducing firms periodically to re-state their technological search strategy. The answers firms come up with, are likely to be specific and idiosyncratic rather than general and easily transferable.

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We conclude here our examination of the nature of the local technological search efforts undertaken by manufacturing firms in LDCs. Let us briefly summarize some of the ideas and findings presented during the course of this essay.

a. The notion of technical information being freely and instantaneously accessible to every other economic agent constitutes a misleading description of reality. So it is to think in terms of a 'technology shelf' from where LDCs can costlessly and timelessly draw the relevant technical knowledge and information on which to base their industrial expansion.

b. Technical knowledge constitutes a very peculiar factor of production indeed. It has some of the properties of the so-called 'public goods', increasing returns to scale and uncertainty underlie both its production and utilization, and so forth. On account of such properties the efficiency of competitive

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64/ A research venture in this respect is presently being undertaken within the framework of the IDB/ECLA/UNDP Research Programme on Science and Technology. See: S. Jacobsson: Technical change, skill requirements and intervention policies in the machine tool sector. The case of Argentina. (Outline for a research piece intended as a doctoral dissertation for the University of Sussex, England.) Mimeo, March 1980.

resource allocation breaks down and appropriate forms of intervention need to be deviced.

c. The nature of market failure seems to be rather different in DCs and LDCs. There is more uncertainty, imperfect appropriability, etc. underlying the generation of basic scientific knowledge than those confronted in dealing with the generation of specific engineering information. Also, an almost complete absence of a set of risk markets makes the case of LDCs a rather particular one, demanding 'tailor-made' instruments for intervention.

d. Besides the previously mentioned properties technical knowledge and information are normally characterized by: 1. Incomplete specification, 2. Imperfect understanding and, 3. Some degree of inimitability, i.e. "There are not two similar factories in the world, even if one has been thought as a carbon copy of the other".

e. The package of technical knowledge and information employed by manufacturing firms in LDCs differs quite significantly from the one employed by industrial enterprises in more developed societies. The differences are due, on the one hand, to the previously mentioned features, i.e. tacitness, imperfect understanding and inimitability (these differences prevail even among different firms in DCs) and, on the other hand, to the rather peculiar structural characteristics of LDCs which make the technology developed in more mature countries either economically unprofitable or technically unviable in LDCs.

f. Concerning the structural characteristics of LDCs which make it unprofitable or technically unviable to replicate in their environments packages of technical information previously used by manufacturing firms in DCs, the more important ones are: small market size, lack of engineering and entrepreneurial skills, differences in relative factor prices, distortions in information, market imperfections, a high degree of protection, etc.

g. A package of technical information useful to perform a given economic activity, i.e. the production of a good or service, will normally include technical data concerning: a. the engineering design of the product (or service) in question. b. a production process, or engineering routine to produce it and, c. an industrial organization arrangement useful to perform the activity. Miriads of alternative combinations among these spheres can be imagined, as each one of them is conformed by 'blue-prints', instructions, and all sort of different technical documents and procedures.

h. Differences in technology as between DCs and LDCs will normally appear in all three of the above mentioned technical spheres, i.e. in aspects of product design, of production engineering and in the area of industrial organization. Such differences tend to be rather more significant in technical matters concerning the production process or engineering routine as well as in industrial organization and production planning.

i. Choice of technique in LDCs seems to be strongly dominated by scale considerations. Relative factor prices seem to play a role in determining entrepreneurs technological choices but of lesser importance than market size. Significant inter-industry differences seem to prevail in this respect.

j. As a consequence of market size continuous flow, highly automated, technologies, which are normally chosen by manufacturing firms in DCs are ruled out right from the begining by industrial firms in LDCs. Production facilities in LDCs are frequently just between one-tenth and one-fifth of the size of comparable plants in developed countries.

k. In such circumstances the plant 'lay-out', the type, cost, etc. of the equipment and machinery, the overall organization of production, as well as the economies of scale that could be captured, the nature of the technical changes that can be incorporated to the production facilities, etc. will all be dramatically at variance with those characterizing a continuous flow production facility of the sort normally employed in firms in DCs.

l. A continuous flow manufacturing plant tends to be product-specific, is organized in 'line', the production cycle is minimized and both product design and the production process tend to be highly standardized admitting little or none ad-hoc on the job changes. Contrariwise, a discontinuous plant tends to be organized in 'shops', the capital equipment is of a more general nature, there is a great deal of flexibility concerning the plant's 'lay-out', the product admits custom ordered changes, etc. Size of batch in this kind of plants is an important determinant of production efficiency and costs.

m. Market size is by no means the only reason on account of which manufacturing plants in LDCs do not constitute a close replica of production units in DCs. A much higher degree of vertical integration, as well as various differences in relative factor intensities have all been noted during the course of different case studies.

n. Many large and medium size manufacturing enterprises in LDCs carry out systematic 'in house' technology generation efforts in areas of product design, process engineering and organization and planning of the production operation at large. Expenditure in the region of 1-2% of the value of output in such technical activities is not uncommon in the Latin American industrial escenario.

o. The above mentioned technical departments -which tend to become independent and specialized engineering units once the firm has attained a certain minimum size and complexity- employ pilot plants, prototypes, and other forms of experimental and information-gathering and processing equipment in order to generate a steady flow of 'blue prints', technical monographs, instruction manuals, etc.

p. 'In house' technological search efforts seem to be undertaken in a sequential order, begining by product engineering aspects and proceeding, after a few years, with process engineering and production planning and industrial organization.

q. Such sequential order in technology generating efforts seems to be associated, on the one hand, with market regime and competitive climate prevailing in a given branch of manufacturing production and, on the other, to a gradual process of accumulation of engineering skills which obtains pari pasu with the passage of time, the expansion and sophistication of output, and the capability for gathering and interpreting the flow of technical information, generated by the production operation. Changes in relative factor prices seem to influence the selection of particular technological search efforts, probably to a greater extent than what they have been seeing to influence original choice of technique.

r. As far as firm-specific variables are concerned physical bottlenecks in the available plant and equipment, scarcities in raw material markets, degree of product's maturity and availability of substitutes, etc. frequently call for 'problem-solving' technological search efforts of one sort or another. Also, an autonomous component of company's perception of technical developments in the knowledge frontier could become an important source of inducement for technological search efforts.

s. Concerning market-level variables, market regime and competitive climate seem to be crucial determinants of technological behaviour. Monopolistic market situations have been observed to induce technological search efforts of the 'output-stretching' variety, whereas a more competitive atmosphere was seen to be associated with either product differentiation efforts and/or with cost-reducing innovation.

t. Various different macroeconomic variables also affect technological search efforts. Among them: the rate of interest, the cost of new capital equipment -as seen by the private entrepreneur after taking into account subsidies, preferential import conditions, etc.- the rate of demand expansion, the overall level of tariff protection, etc. all seem to influence entrepreneurs as far as technological behaviour is concerned. An increase in the rate of interest seems to encourage the search for reductions in the production cycle. A subsidized cost of new capital equipment induces an early scrap of existing facilities vis a vis the option of 'stretching' them through a more intensive use of engineering services. Contrariwise, relatively cheap engineering services might induce a longer-than-justified life cycle and an over-extended use of outmoded equipment, etc.

u. Given the fact that most large manufacturing plants in LDCs begin their operation by importing production equipment, technical 'blue-prints', etc. from more developed countries the initial years of company operation are normally absorbed by learning efforts whose major purpose is that of de-bugging and adapting to local conditions the imported equipment. A growing proportion of locally-generated 'disembodied' technological changes seem to be implemented with the passage of time. As a consequence of this the overall technological package employed by LDCs firms tends to become increasingly specific and idiosyncratic as time goes by.

v. Far from being passive recipients of foreign blue-prints and technology Latin American manufacturing entrepreneurs seem to respond in particular and idiosyncratic ways to micro, market-specific and macro variables. Their response is likely to be more noticeable when changes in their environment are more dramatic and therefore more clearly perceived.

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