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Flexible Automation and Less Developed Countries: Is CIM Only a Threat to the LDCs?

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Foreword

There are many hypotheses about the impacts of advanced manufacturing technologies on the industrial structure and on the competition between countries. Especially the possibilities of developing countries to keep up with the recent trends have been one of the key issues under discussion. Pentti Vuorinen and Erkki Laukkanen from Finland were at IIASA in summer 1987, participating in the YSSP. They were working for the CIM-project, making an assessment of flexible manufacturing technologies in developing countries.

The present working paper, written by Pentti Vuorinen, gives a summary of their work and presents the main conclusions. The paper is an interesting and good overview of manufacturing trends, national programs and current industrial problems in developing countries. It forms a sound basis for a global impact assessment of CIM technologies.

Prof. F. Schmidt-Bleek	Prof. J. Ranta
Program Leader	Project Leader
Technology, Economy, Society	Computer Integrated Manufacturing

Summary

In this paper, the preconditions and effects of introducing flexible production technologies in LDCs are taken into consideration. The problems of industrial development in LDCs, especially in NICs, is approached by studying the results from previous research work and by evaluating competing theories of technological development in LDCs.

Two contradicting hypotheses are presented, but neither of them is accepted as such. Both of them are critisized for being too simplifying and too general. The most common theoretical explanation for international industrial development, the theory of comparative advantages, is also taken under critical inspection in chapter 3. As an over all explanation for LDC development or policy guideline it is rejected, and rather accepted as a normative tool for planning sequential development paths for industries in LDCs.

In chapter 2., a brief historical survey on the development of some industrial branches in various LDCs is presented. The effects of multinational corporations, the development of R&D activities and supply of skilled manpower are taken up as special themes. The features of LDCs are compared to each other and occcasionally to some older industrial countries as well.

The picture is enriched with an excursion to recent developments in manufacturing technologies in chapter 4. The problems of producing and applying flexible automation technologies in LDCs are summarized and formulated into a reseach approach in chapter 5. The adopted approach is of a more conrete, more historically and institutionally oriented nature than the most commonly used research methods.

In chapter 6, some countries are considered as possible targets for a more concrete study on flexible automation and LDCs. In the final chapter, the research approach is developed further and summarized into a sketch for an empiric study starting as a comparative survey between three pairs of countries.

FLEXIBLE AUTOMATION AND LESS DEVELOPED COUNTRIES: IS CIM ONLY A THREAT TO THE LDCS?

A literature survey on the industrial technological change in less developed countries with a proposition for a further empiric study

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FLEXIBLE AUTOMATION AND LESS DEVELOPED COUNTRIES: Is CIM only a threat to the LDCs?1

1. INTRODUCTION: GLOBAL INDUSTRY AT THE CROSSROADS?

The global industrial system is facing major changes. They appear in many economic and social issues: Severe recessions, exceptionally strong cyclical movements and worsening labor market mismatches are common in most industrialized countries. National economies are facing deep financial problems and the crisis in the world monetary system has grown worse. New protectionistic measures and barriers for trade are being introduced.

The changes have various and often interrelated reasons. In the long run, however, it is not difficult to see the chronical cost crisis of manufacturing industry in the developed countries behind many of them. The varying ways of answering to the challenges of falling profits are responsible for a lot of these new features in world industry (c.f. Lipietz 1984, Harris 1986 and others).

Most of these issues are related to technolocigal change and industrial automation. Particularly new technology based on microelectronics is challenging the old manufacturing patterns - it has become the most important single means for companies and nations to cope with economic problems. This key technology affects both the industrial products and the processes. Implementing microelectronics into production processes even has wide societal implications. It affects the organization of production, intercompany business relations and locational behavior of firms as well as the institutional settings between public and private organizations.

1.1. Two Contradicting hypotheses

If we take a look at the industrial transformation from the less developed countries' angle, the East Asian NICs seem to have benefited from the rapid growth in the role of electronics in the world economy. For many other LDCs the opportunities and challenges of modern technology are only beginning to manifest themselves. While manufacturing automation is diffusing quickly in the developed countries, the future success of the NICs is not self evident either. Two contradicting hypotheses are often proposed (e.g. Hoffman 1986):

> 1) Microelectronics and its applications offer an opportunity for LDCs to take a technological 'leapfrog' over the long-standing problems which so far have constrained their development efforts.
>
> 2) The technological gap between the developed and developing countries is irrevocably widening. Automation in the developed world will undercut the LDCs' ability to compete in the international markets. On the other hand, an open embrace of new technology without sensible politics to mitigate negative social impacts would be likely to have very little beneficial effect on the development process of less developed countries.

Production technology is the focal point of the latter hypothesis. It is based on the assumption, that the prevailing trend towards world wide sourcing and global production chains is about to break when the patterns of relative advantages, costs and benefits are changing. The new relative advantages for developed countries rise from the diffusion of flexible manufacturing automation. This poses major problems for less developed countries.

The underlying line of argument goes, according to e.g. Roobek and Abbing (1986): The relative advantage for LDCs - and the main basis for their industrialization - has been low cost labor. Now, when benefits from automatioutweigh low labor cost benefits, they are losing this advantage. Labor costs are no longer critical, and the urge to automate outweighs the urge to localize production near cheap labor resources. Modern industry will, from now on, be located near markets which are mainly within the so called Triad region - Europe, North America and Japan. Ohmae (1985) finds three main causes for this change in locational patterns:

a) New production structures related to FMS, CIM and other microelectronics based technologies and new manufacturing ideologies (JIT).

b) Large markets and common consumption patterns in the Triad region.

c) The protectionistic barriers that are increasingly used in the developed countries to protect the domestic production against import competition.

There are also arguments opposing the reasoning above. The most common is, that LDCs now have the opportunity to narrow the technology gap by jumping over some intermediate levels of technological development and implementing directly the most developed techniques. The relatively modest level of industrialization would even assist this process, while the existing capital stock to be replaced by modern microelectronics related technology is not so valuable.

1.2. Dangers of Simplifying

The whole picture may, however, not be so simple. Neither of the hypotheses can be taken as a complete description of the possibilities. The history of industrialization in some LDCs so far shows, that no theoretical scheme can give an ex ante prediction of the future development (c.f. Harris 1987). The success stories of East Asian NICs have not followed the predictable paths of development based on obvious relative advantages. The simplifying assumpitions can be questioned already in the premises: Are all LDCs really so dependent on MNCs? Is cheap labor their only resource and are the locational decisions of foreign companies only based on straight forward labor costs? Some preliminary considerations need to be taken up before a more elaborate discussion:

1) The question of **cheap labor** resources. The remarkable industrialization in some LDCs during the 60s and 70s has not

been only due to the resources of cheap labor. There are other countries, with very modest industrial showing, that have a lot more obvious relative advantage of cheap labor. On the other hand, labor can still in spite of automation be a critical supply factor (Harris 87, Hoffmann 1986)

2) The NICs or other industrializing LDCs are not totally **dependent on multinational corporations** or on imported technology. The growth of domestic industry has been rapid in many countries and the importance of foreign manufacturing plants varies between different LCDs. The relationships between domestic and foreign companies are also quite many sided and differ in various industrial branches and countries.(c.f. Grunwald & Flamm 1985, Woronoff 1986).

3) **Locational choices** are not based on just one or two siomple factors. Industrial development is a more comlicated process. This is especially true for diffusion of new technology: it is the outcome of evolutionary processes whereby the interaction between agents induces changing incentives, selection mechanisms and learning processes (Dosi et al. 1986). For example, the production structures, institutional settings and industrial infrastructures in NICs are not the same they were at the beginning of the industrialization process.

We are, evidently, dealing with a question of a change in the whole global manufacturing system with diverse contradictory trends and varying concrete developmental treats of national economies. This is not easy to investigate; the research approach should comprehend development theory, theory of technological change, the study of diffusion of innovations and various issues of international relations and trade. On the one hand, there is no way to reveal a common path of evolution or the trends of change based on plain theoretical reasoning. On the other hand, empirical studies, as such, do not contribute much more than new cases and examples. An unified approach of theory and empirical study is needed.

1.3. Structure of the Report

In the following, the challenge posed by flexible manufacturing technologies to LDCs is approached from different angles. In chapter 2 the history of industrialization in LDCs since the 60s is discussed as a starting point.

In the next chapter, the theory of comparative advantage is taken under investigation. Some main features and variations of this textbook explanation for changes in international economy are surveyed.

In Chapter 4, the technological side of the problem is taken up and the recent advances in manufacturing techniques are discussed within a more general framework of technological change.

In Chapter 5, the main problems for a further study on LDCs and automation technologies are summarized on a general level. In the next chapter the concrete development in some singles LDCs and areas are taken into consideration. The industrial transformation in the Republic of Korea is described in more detail in appendix.

The general set up for the proposed future study will be drafted in Chapter 7.

2. INDUSTRIAL DEVELOPMENT IN LDCs SINCE THE 1960S

2.1. Industrial growth in general

The growth of industrial capacity in the LDCs, was mainly initiated in the 60s although it was not until the global slowdown in the 70s that the phenomenon became widely discussed. Already in the years immediately after the World War II, rapid industrialization was in LDCs regarded as the key to economic prosperity and international influence. But domestic demand was nevertheless more important than exports. Internal approach and largely from west initiated relationships were reminiscent of the earlier colonial domination. Cooperation with developed countries was mainly Wests' provision of experts (c.f. Ballance & Sinclair 1983).

Regarding the rapid industrialization in the 60s and 70s, Turner may (1982) be right, when he argues, that the growth of industry in a number of LDCs is not "posing fundamentally new problems to the world economy, but that they have emerged at the wrong time... at the time of slow growth and high unemployment there is obvious skepticism about the working of the economic adjustment process". Total industrial development, measured with the growth of value added, has been faster in LDCs than in advanced market economies both in the 60s and 70s. The figures for the 70s in table 1. show, that the difference in growth has been widening.

Table 1. Growth of manufacturing value added (MVA) by economic grouping, selected periods (%) (Ballance & Sinclair 1983)

Period	LDCs	Soc.	Adv. market economies
1960-70	7.3	9.6	6.2
1970-81	5.8	7.0	3.0

If we take a nearer look at the time series for distribution of world value added between different groups of countries, the picture becomes clearer. The share of LDCs has been growing since the early 50s, and ~~in~~ particular the growth in the share of the so-called SICs/NICs has been showing. The top 8 countries in this group have been responsible for about 70 % of the total LDC MVA added by 1980.

Table 2. Estimated shares of world MVA (ibid.)

Country group	Year 1938	1948	1953	1963	1970	1975	1978	1980
Adv. market ec.	61.0	72.2	72.0	77.3	73.4	67.5	66.8	65.2
- old centers	41.0	58.7	55.2	46.1	39.6	35.7	35.0	33.4
- recently ind.	13.8	6.5	10.4	22.9	25.8	24.2	24.5	24.3
- others	6.2	6.9	6.4	8.3	8.0	7.6	7.3	7.7
Adv. soc. ec.	34.5	22.1	23.2	14.6	17.8	22.5	22.9	23.8
LDCs	4.5	5.7	4.8	8.1	8.8	10.0	10.3	11.0
- SIC's	3.3	4.0	3.2	5.5	6.0	7.0	7.2	7.7

Countries by groups:
- Old centers: Belgium, France, Luxembourg, Netherlands, Norway, Sweden, UK, USA
- Recently industrialized: Greece, Ireland, Israel, Italy, Japan, Portugal, BRD
- SIC's: Argentina, Brazil, Colombia, Egypt, Hong Kong, India, Malaysia, Mexico, Philippines, Singapore, Korea, Thailand & Turkey

Focusing on more recent ~~country~~ try wise developments (table 3.), the growth in the core of NICs - Hong Kong, Taiwan, South Korea and Singapore - seems to be continuing, though the era of 'hypergrowth' has, obviously, ended. The prospects for countries like Brazil, Mexico and Argentina do not look as positive: for their part, figures for manufacturing are declining. Also in Yugoslavia are topics like 'where did the Yugoslavian miracle dissapeare' quite relevant.

Table 3.: Average change in MVA and GDP in some countries, % per year (UNIDO 1986b)

Country	MVA 1975-80	1980-83	GDP 1975-80	1980-83
USA	4.0	1.2	3.6	1.3
Mexico	8.3	-1.1	7.5	0.7
Brazilia	9.0	-4.0	8.2	-1.1
Argentina	0.3	-3.9	2.6	-2.9
Hong Kong	20.3	10.0	16.0	7.3
Taiwan	17.5	6.1	12.5	5.9
China	..	..	6.8	8.0
India	6.0	4.4	3.9	3.8
Japan	8.6	2.1	5.5	3.3
Korea, rpl	16.8	10.9	8.8	8.2
Philippines	8.4	4.2	7.6	2.8
Singapore	16.1	2.2	11.9	9.2
Finland	4.7	3.7	3.3	2.8
Sweden	0.0	0.0	1.4	0.8
Yugoslavia	6.2	1.5	6.3	0.4
Hungary	4.5	3.0	6.1	1.8

A comparison of figures for growth in manufacturing value added (MVA) and in gross domestic product (GDP) shows, that the economic development ~~has~~ been carried on by manufacturing industries in the South East Asian NICs up to the end of 1970s. After that, the figures for manufacturing growth are not much above the average level of figures for the developed countries. This is most obviously evident in Singapore, where other sectors have clearly taken lead in the economic development. This implies, that the era of initial industrialization is over, and that the mode of economic development is approaching the mode in developed countries - with all the main aspects of a 'postindustrial' economy present.

It is not hard to see, that one of the main results of this growing industrial strength of the SICs/NICs has been the disappearance of the 'Third World' as a common - factual and/or politico-ideological - entity. The most advanced LDCs have, in fact, more in common with the industrialized North than with most African states.

It has also affected the economic theories of industrial development and international industrial relationships. The general development theories - based on neoclassical economics and Rostowian stages of growth - as well as the marxist inspired dependency theories, which both were purported to fit all LDCs, have been largely swept aside with the growing recognition of the increasing disparities between these countries (c.f. Harris, ibid.). A new general theory is still missing. If it ever comes up, it is certainly flavoured by considerations of flexible manufacturing and the new production modes in LDCs with diversified paths of development in the context of changing global settings for trade and production of manufactures.

The Question of foreign debt

Lack of capital has been one of the main constraints for growth in LDCs. Strategies to overcome these straits have been many: to focus on domestic savings, to invite foreign capital investments and to borrow from foreign banks. As the value of the US dollar has been raising and the overall demand on the world market declining, the last strategy has led many LDCs into a quite difficult situation.

Most LDCs own debts mainly to the banks in developed countries. In the beginning of 1980s the service costs of these debts rose in many LDCs to a level which exceeds the value of their exports. The situation is worst in big Latin American countries like Brazil, Mexico and Argentina. Because of poorly developing manufacturing value added the troubles in these countries are multifying.

In most cases the debts to US banks ~~came~~ up to over 50 % of all debts to banks in developed countries in 1982-1983. But thereafter the situation in the banking world have changed rapidly. Japan has become - mainly because of the strong yen - the biggest lender in the world. The devaluation of US dollar has worsened the situation of US banks: within the 10 biggest banks of the world, there are no US banks anymore. Accordingly it is obvious, that the role of Japan is strengthening in international banking world while the role of USA is declining. It is quite uncertain, what this could mean for the borrowing countries. The situation of countries with tight economic connections to Japan might become better. This could imply, that the changes in banking world might support the developments in South East Asian countries.

Table 4: Debt and dept serving costs in some LDCs (Aronson 1986)

Country	Debt service as % of export values (1983)	Debt owed to ind. country banks (bil.$) (june 1982)	Debt owed to US banks (bil.$) (end 1982)
Brazil	117	55.3	20.4
Mexico	126	64.4	24.4
Argentina	154	25.3	8.2
South Korea	49	20.0	11.0
Egypt	46	5.4	1.5
Philippines	79	11.4	5.7
Taiwan	19	6.4	4.8

The high debt level has not, however, prohibited, for instance, South Korea or Taiwan from being successful in their industrial development and renewal. Although the total external debt of South Korea in 1982 was at about the same level as that of Argentina, the burden caused to the economy was lower. The service costs of loans counted for 49 per cent of the value of the South Korean exports. For Argentina, the corresponding share was 154 %. This means, that the Korean export success has been by far better.

The high level of debts in the Southern American countries may not, however, as severe a problem as it seems to. Since the debt crises in 1982, the big debtors have achieved trade surpluses. This suggests, that favorable changes in their reserve positions will make it possible for them to choose among a rather wide range of reasonable policy options. For instance because of Mexico's strategic geographical position and the complex pattern of the relationships between the US and Mexican economies (e.g., energy, manpower, capital and technology), it would be quite unlikely that the US government would refuse to grant new loans or more flexible debt conditions for Mexico - if the alternative would be to see Mexico join a debtors' cartel. (Hojman 1987).

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However, the aggregate figures of manufacturing development or debt situation do not tell much of the changes. The whole history of industrialization, the institutional settings and policy considerations must be taken into consideration. In the following some of the principal themes in the history of industrialization in LDCs are discussed.

2.2. Main fields of industrialization in the LDCs

The industry in LDCs has been mainly labor intensive manufacturing, but the product mix began to diversify significantly in the late 1970s. The Third world countries achieved notable gains in electronics related products and certain categories of non electrical machinery (agricultural and textile machinery, machine tools). A few NICs have dominated these branches, but both in garments and electronics other countries also began to make an impressive showing.

The main market for these LDC products has been in the developed countries (ca. 58.4 % in 1980). In some product categories LDCs have been totally dependant upon retailing access to OECD markets. During the 70s the policies in many less developed countries were drafted to the direction of a wider product mix and OECD market. In developed countries this has led to counter actions, pressured especially by leading dstic firms. The consequence has been raised levels of tariffs to LDC products. Developing countries were finding it increasingly difficult to sustain the high rates of export expansion, quite apart from the problems posed by microelectroni cs.

Among the most important industrial sectors in the history of LDC industrialization have been:

a) **Electronics** - semiconductors, computers and consumer electronics. This sector is the heart of the new technological paradigm. Semiconductor assembly has been one of the main fields for multinationals offshore assembly and in consumer electronics and computers even many domestic LDC firms have had showing success.

b) Mechanical and **engineering** industry - machines, machine tools and other metal products, The capital goods for other sectors are mostly produced within this industry. Together with electronics, this sector forms the core of technologically dynamic industry.

c) **Textiles and clothing** industry. This sector is one of the most typical branch for manufacturing based on cheap labor resources. Production technology is being modernized with a slower pace than in mechanical industries.

d) Manufacture of **Vehicles** is a sector, where advanced flexible automation technologies are used widely. There is quite remarkable vehicles production in many LDCs. Although for example cars are mainly produced for domestic market in LDCs, some NICs have also had noticeable success in exporting vehicles.

e) Manufacture of **plastic** products may not be among the most important industrial branches in LDCs yet. But it is quite likely to grow in importance. Products from this industry are in many fields substituting metal goods. Prospects for flexible manufacturing automation are also more promising within this branch than for example in clothing industry. This branch is not covered by the following survey, but it should included in further studies.

2.2.1. Electronics

The electronics complex is at the heart of the new technological system. It is also on the way to become the single most important sector in the world economy. Electronic industry and its products will be the most important carrier of technological change in LDCs on short to medium term. Its importance is, according to fx. Hoffman (1986) based on many factors:

a) Electronic consumer products are already affecting consumer patterns even in the poorest countries. Microcomputer offers enormous scope for immediate applications which could yield substantial social benefit.

b) This sector - because of the pervasive character of microelectronics - will increasingly come to play a role in economic development akin to that attributed to the capital goods sector.

c) Electronics related skills will have wide applicability throughout the economy first to adapt imported process and product technologies to local conditions, and eventually to develop indigenous technologies. They are also necessary for a successful implementation of industrial automation techniques. So, the greatest opportunities for developing countries to enter new markets seems to be in electronics products.

The role played by LDCs as exporters of electronics products has already been prominent. The annual growth rate of LDC exports in seven categories of electronics products exceeds that of world exports by more than two - three times. Hong Kong, Singapore and South Korea are exceptionally strong in virtually every product category. Taiwan, Malaysia, the Philippines, Mexico and Brazil form the other important group. The countries' performances vary remarkably in different electronics product groups.

a) Consumer Electronics

In the initial expansion of consumer electronics industry in Asia, the multinational corporations involvement in offshore assembly for export was a crucial element. LDCs have mainly been successful exporters in low technology products manufacture of which entails only limited local linkages. A number of countries have, however, succeeded in developing a strong local industry in certain mature products where design has standardized and process changes are of incremental nature. Even in Thailand where the most components are imported, there are seven large TV & radio assemblers (Hoffman, ibid.).

The emergence of Asian countries as the dominant world source of consumer electronics products was among the principal features of electronics industry during the 60s and 70s. This persuaded many others to attempt to follow the same path. However, where the export market in more sophisticated products is the intended objective, a whole new set of difficulties has arisen. This suggests that some form of mutually beneficial co-operation with the MNCs will be necessary. When international competitiveness is increasingly determined by other factors than low wages, considerable barriers for entry to new entrants are likely to rise. Even in the successful producer countries employment has not any more grown as fast as production and exports.

In South East Asia dependence on Japanese MNCs is strong either for product design know how or for components. Japanese firms are proving extremely reluctant to provide product and process technology, preferring to reserve production of these products for their domestic facilities where they can quickly exploit scale economies to achieve market dominance. This can cause problems. Referring to Clark & Cable (1982), Hoffman stresses that:

> "In the past Japanese producers directed their attention to Asian countries as a place for overseas production but there is now a

> move to divert investment to developed countries in North America and Europe. No substantial expansion beyond the current fairly active situation is expected" .

Other sources (fx. Harris, idid), however, point that Japan has not even before been active in setting up assembly plants in the neighboring South East Asian NICs. Its is mainly the small and medium sized Japanese companies who only have one or two foreign plants that have set up assembly plants for example in Korea. These plants are also mainly producing for the domestic markets in the location country. We will return to the question of differences in manufacturing location policy between MNCs with Japanese and American background later.

b) Computers

The computer industry is still dominated by US firms. Rapidly growing small firms have emerged with the introduction of microcomputers and high growth rates have led many established firms from other parts of the electronics complex to enter the market. This has led to intense competition in an already fierce and crowded market.

PCs are, however, extremely important for the development of LDCs. They can be seen as basic tools for the modern technological systems. For example, even advanced manufacturing technologies can widely rely on PCs. They will involve the increasing domestic and commercial use of 'stand alone units', which can integrate to systems via local area networks. These can further merge via tying domestic terminals to subscription based interactive information systems.

Production of computers, peripherals and related components for export has grown fast in some LDCs. The sourcing strategies of foreign firms and export activities of local firms mean that a small group of NICs have become important forces also in the world computer market.

Some LDCs have even imposed protective policies for their domestic computer manufacture. For example Brazil and Mexico have used a 'market reserve' strategy with some success. But problems have occurred, too: domestic PCs are often produced with very high costs and and they are not seldom of inferior quality when compared to international norms. It is also an extremely hard task to shift domestic start-up firms toward self-sustaining growth path defined by local innovation and support by the expansion of local supply of components. The efforts are opposed for example by the aggressive responses from foreign firms barred from what they see as extremely lucrative markets.

c) Computer software

Software may be even more important than the manufacture of computer hardware, at least in regard to export prospects. Software costs are rising and demand is increasing enormously. Throughout the developed countries there is a growing shortage of trained software personnel. For LDCs themselves software is necessary: without a software capability there can be no real indigenous electronics or mechatronics production capacity in the country, nor can the country go very far in adapting available systems to its specific needs.

Many LDCs face considerable local need for computing systems. The systems available are often not suitable to local needs. Hoffman (ibid.) gives an illustrative example of overcoming the problem: in Argentina a few skilled ex-employees of IBM, NCR and Burroughs set up their own firm to supply highly 'location specific' sets of software packages to the banking community. In early 80's they were designing and assembling both peripherals and microcomputer systems, selling ca 50 packages a month.

Development of applications capability may be one of the best and most cost-effective ways through which even smaller and poorer developing countries can begin to build up a capacity in electronics. This capability is crucial for introducing all kinds of advanced industrial automation techniques into the manufacturing processes. Software capability will, in fact, determine a countrys' ability to develop an independent capacity in electronics and other modern technologies.

According to Hoffman, developing countries have good prospects to export software and computer services to the developed countries, because:

a) Large demand of products and services is outstripping the supply capacity of the industry in the advanced countries.

b) The highly fragmented market for products means that there are many market niches where small firms can gain entry provided they have a reliable product.

c) The skill barriers to entry are really quite low.

d) Capital costs are low as well.

In LDCs unit costs of software development can be 3 - 10 times under that of developed countries. But, there are countervailing trends as well:

a) Variety of programming tools are being developed and this will lead to substantial cost reductions in developed countries.

b) LDCs software exports are almost all tied to the operations of MNCs who subcontract only relatively simple processing tasks to their offshore locations. Though there are also possible benefits from this entry route: these subcontracting may provide a springboard - like in hardware - which NIC firms can use to launch their independent capacity.

c) Distance problem is present, but can be overcome with telecommunications or subsidiaries in the main markets. This is already happening, e.g. in Silicon Valley.

e) Semiconductors

Semiconductor assembly has been the main field of multinationals operations in most NICs, particularly in South East Asia and Mexico.The offshore assembly started already in 1962.

Table 5. Market Shares of the Principal Exporters of Semiconductor Devices Brought into the United States under Tariff Items 806.30 **and 807.00, 1969 - 1983** (Flamm 1986)

Region and country	Year 69	73	76	80	83
West	25	20	15	11	14
Canada	2	1	*	4	4
Mexico	22	19	11	5	5
El Salvador	0	0	3	2	2
Haiti	0	*	*	*	*
Barbados	*	*	*	*	3
Antilles	1	*	*	0	*
Brazil	0	0	1	*	*
Europe	14	7	2	*	*
UK	*	0	0	*	*
Ireland	12	4	2	*	*
Portugal	2	3	*	0	0
Asia	61	72	82	88	85
Hong Kong	30	15	9	4	1
Korea	14	17	17	9	14
Taiwan	9	9	6	4	4
Singapore	62	42	32	21	1
Malaysia	*	6	21	30	31
Japan	2	*	*	*	*
Thailand	0	0	*	3	4
Indonesia	0	0	*	2	2
Philippines	0	1	6	14	18
Total value of 806/807 imports (mill. $)	127	413	879	2506	3383

The multinationals investments in new IC production facilities in LDCs have slowed down quite considerably since 1974. For new countries, the traditional way of entering into the export market via final stage assembly under MNC control appears to be closed. The strategies seem to differ between various LDCs: MNCs are in fact creating regional production, testing and distribution centers in South Korea, Singapore, Taiwan, Brazil and Mexico.

In semiconductor industry, the barriers of entry may be too high for new countries. Already the start up investment costs are very high. Chip manufacturers must stay near the forefront of product technology or else rapidly lose their market share. Therefore, the needed level of R&D may also be beyond the capabilities of most LDCs. A large number of well trained and highly specialized scientists, technicians and electronics engineers are required.

Hoffman (ibid.) argues, that the trend toward rapidly moving technological frontier, regional concentration of MNC investments and expanding national capabilities within the NICs, which are evident in the semiconductor industry, parallels the developments in the machine tools and clothing industries. Smaller LDCs are in danger of being permanently excluded from gaining access to the most rapidly growing parts of electronics markets.

From a policy perspective this makes the development of national component design capability essential, since the key to exploiting the technology's application flexibility will rest on having ability to design circuits. In many countries even production for domestic markets may be feasible.

The present conditions governing entry into IC market differ significantly from those of consumer electronics, software and computers. For these three sectors there are some common factors, that are not - at least not yet - present for the semiconductor sector:

a) Because of the rapid diffusion of microelectronics within the electronics complex, a very wide variety of product niches are emerging with characteristics which could allow much greater participation of Third World firms.

b) The successful exploitation of these product niches depends much more on product design capabilities than in process technology.

c) In spite of MNCs major role, small firms enjoy distinct advantages in responding to or anticipating specific and/or changing market demands in many product categories.

d) For a number of products, efficient scales of production are quite low - domestic market opportunities can be much more easily exploited to nurture the development of small firms without forcing them to move to export markets too directly.

The main question for future is whether or not the trends of technical change that are dominant in semiconductor industry will expand to other segments of the electronics complex. Or is there emerging also within the semiconductor area a sphere of 'appropriate technology' suitable for LDCs to produce circuits to be used in their own products?

2.2.2. Machines, machine tools and metal products

In many NICs the capital goods sector has been a central target area for governmental policy and support measures. Production of capital goods, in particular machines and machine tools, is often regarded as the backbone of a nations industrial structure. This seems to be a fact for LDCs successful in gaining notable industrial strength, too (Erber 1986, Chudnovsky 1986). Their machine and machine tools manufacture has achieved quite remarkable results.

The sector is also of great importance for the development and diffusion of modern automation technologies in LDCs. In particular, when a country is targeting for example on the production of advanced electronics or metal products, it obviously needs an up to date machines and machine tools industry. The sector not only supplies the economy with the needed machinery but also with the skills necessary in installation and maintenance of imported machinery. An up to date machine tool industry is further needed for the adaption of more complex imported flexible automation systems.

However, it is not always grounded to try to produce domestically all necessary capital equipment. The make - import decision is quite important when thinking about the national strategy of industrial development. It may often be a more successful strategy to import the most of modern technology, and have own production only to such and extent, that adaption, maintenance and incremental development of imported equipment succeeds with little extra effort.

On the other hand, the sector itself is an important user of flexible automation technologies. In many LDCs the same multi sector corporations - with the core in engineering industry - are often responsible for the most part of both production and use of flexible automation in the respective country. The problems relevant in production of automation equipment will be discussed further in chapter 4.2.

The most important single feature in the international machine tool market has been the swift rise to dominance of the Japanese. The main reasons for this have according to Hoffman (ibid) been:

a) Major domestic users of machine tools such as the automobile industry undertook an intensive innovative effort to develop these tools for their own use.

a) Producers set out to capture scale economies in machine tool production based on extensive use of automation technologies and via product standardization so that unit costs were considerably reduced.

c) The Japanese identified particular market niches at the lower end of the cost/complexity scale and designed superior products to fill these niches.

d) The producers established an extensive world wide network for marketing and after sale service which served to cultivate demand among users normally ignored by other firms. Now the Japanese network covers over 130 overseas locations.

e) Japanese machine tool producers established close design links with suppliers of CNC units and due to the scale of their production were able to reap substantial unit savings in purchasing the control systems by buying in bulk - achieving unit reductions of up to 35 %.

The last point is the most important - the CNC unit accounts for about 25 % of total costs, so this gave an important boost to their price competitiveness compared with conventional producers who manufacture machine tools in small batches.

The use of CN-controlled tool machines has grown quite fast mainly in some NICs. In South Korea the share of CNC lathes in total lathe investment grew from 2.4 % in 1977/78 to 34 % in 1981/82 . In Taiwan the respective shares were 7 % in 1977/78 and 20 % in 1981/82. On the other hand, the overall diffusion of NC machines into LDCs is still very modest. In Argentina, for example, NC tools accounted for only 6-9 % of capital good imported between 1978 - 1982 and NC lathes accounted for 38 % of all imported lathes. In Brazil, there were 834 NC machine tools in 1983 - less than 400 in 1980 - of which 422 where domestically produced.

Table 6. Production of and demand for CNC lathes in some countries (units) (Jacobsson 1986)

Country	Production	Demand
Argentina	10 (1983)	45 (1981)
Brazil	120 (1982)	150 (1982)
India	15 (1983)	101 (1983)
Korea	268 (1984)	248 (1984)
Taiwan	347 (1984)	250 (1984)
Sweden	200 (1984)	n.a.
UK	816 (1984)	1449 (1984)
Italy	830 (1984)	494 (1983)
France	616 (1984)	1001 (1984)
FRG	2356 (1984)	1661 (1984)
USA	1524 (1984)	4575 (1984)
Japan	16555 (1984)	10551 (1984)

2.2.3. Textiles and clothing

Textiles were the other important field for multinationals operations. Textile plants in LDCs are usually either domestically owned or joint ventures with foreign firms and not subsidiaries of multinationals. However, this feature is not of much value to the respective countries. The industry is not knowledge intensive, and products are usually designed in the developed countries. Any remarkable local linkages are not either connected to the process of assembly. Linkages further on along the production chain are in rule to the developed countries and nearer to the market.

Since the manufacturing of garments is still labor intensive, the production seems to be moving from the original NICs to countries with greater relative advantages of cheap labor resources. The most important among these are China, Philippines, Malaysia and perhaps also countries in the European periphery. These 'second tier NICs' are now rising with textiles and garments production as the main export industry. In particular, the Chinese garments industry has shown quite remarkable growth figures for export. (Ballance & Sinclair 1983).

The interesting issue is here the development in garments manufacturing technology. Technological change has obviously been slower than, expected (Hoffman & Rush 1983). There are neither any prospects for very fast automation of garments manufacture in the near future. The LDCs may so have some time to gain on the old relative advantages. But on the long run, it is evident that flexible automation techniques will be developed also for garment assembly and that they will be quickly adapted particularly in firms operating in countries with high labor costs. Computerized technologies are already widely used in the side functions - cutting, drafting, designing - of garments production.

This means, that the manufacturers in LDCs should already be prepared to modernize their production technologies. But, in order to succeed in this, they need to development the domestic machine tools and electronics industries. More research and development in the manufacturing technology of garments is also needed, as well as advanced software and systems work for developing the production systems.

2.2.4. Vehicles

Vehicle production seems to be the foremost sector for the use of flexible manufacturing technologies. A remarkable share of world FM systems are installed into car factories, or factories manufacturing car parts. They may also present the best material for comparing the nationally and culturally specific approaches to the idea of flexible manufacturing. For example, American, European and Japanese car manufacturers seem to have rather different work organizations; they also have adopted flexible manufacturing technologies with differing expectations and are based on different types of investment calculations.

Even the targets of flexibility seem to differ. Also the relationships of production organization and production technology in implementing flexilibity are not at all the same in for example the USA, in Japan and in diverse European countries. Where the Japanese most often begin with rethinking the organization and implementing technology to a new organization, it is not seldom to do just the other way round in the US or Europe: first - to install new machines, second - to educate the work force, third - to introduce changes in the production organization only when the system meets with difficulties.

There is quite notable production of vehicles - of both trucks and personal cars - in many LDCs. Though most of them are supplying for the domestic market, various new countries have recently also entered the world market. Taiwan, Korea and Yugoslavia are good examples of recent success in exporting personal cars.

2.3. The multinationals offshore manufacturing

The rapid industrial growth in the West after the Second World War encountered the problem of work force scarcity already in the early 60s'. Diverse countries responded to the challenge of increased foreign competition and rising labor costs with different behaviors. The US firms responded by moving the most labor intensive phases of production to low wage regions, first in the United States and later in the developing world. The Europeans more often preferred importing cheap labor to domestic factories. The Japanese encountered the problem somewhat later, and answered to it mainly by automating production processes. (Sanderson et al. 1987)

In the early 80s some 2 million people were employed in offshore assembly operations worldwide with an annual output of $ 15 billion (Edwards 1984). Offshore assembly grew from 4 % of total US imports in the early 1960s to almost 10 % in the 1980s (Grunwald & Flamm 1985). Eleven developing countries account for 75 - 80 % of world offshore assembly output primarily in the production of electronics goods, and three quarters of all offshore assembly of electric and electronic goods is concentrated in five countries. The most important offshore assembly sites for US firms are Mexico with over $ 3 billion (28 %) followed by Malaysia's $ 1.4 billion (13 %) and Singapore's $ 1.3 billion (12 %) worth of electrical and electronics goods (Sanderson et al. ibid.).

The targets of off shore manufacturing may, however, be quite diverse. The 'original' aim was to reimport subassembled parts back to final assembly and markets in the States. This is still the dominating pattern for American corporations. The US firms locating plants in low wage countries are mainly the big multinationals.

The Japanese pattern of offshore manufacture is quite different. It has never been as important a strategy for companies as in the US and the targets are also different. The firms locating plants in low labor cost areas - mainly in the neighboring East Asian countries - are fairly small. For example Japanese plants in Korea are in most cases the only foreign establishments of these firms (Lo 1985). The big Japanese corporations, on the other hand, prefer establishing plants in the US and West Europe.

In the Japanese case, the main target is not reimport to Japan, and the lower production costs seem often to be of secondary consideration. Choosing foreign plant sites - both in the Asian NICs and in Europe/USA - is more often motivated by the desire to gain access to new markets.

The European offshore establishments (outside Europe) are still of minor scale compared to the US and Japan. They represent a mixture of the two strategies, with focus on the Japanese one. The European firms are using offshore manufacturing more often in the traditional industrial branches than in the high tech area. The operating mode is quite different in these cases: for example, the textiles and garments manufacture in low labor cost countries is usually not carried out by foreign establishments of European firms, but by independent local subcontractors.

The evolution of flexible manufacturing automation has generated speculation about the likelihood of capital-labor tradeoffs will significantly reshape the development prospects of low-wage areas, redirecting future factories to areas of abundant, secure and low cost capital.

A recent study argues, that for the range of generally less sophisticated products currently assembled there, Mexico would retain its cost advantage for all volumes considered. However, for volumes exceeding 310 000 units per year, US flexible assembly begins to show lower unit costs than manual assembly in Singapore. Transportation costs are the dominant factor traded off against lower wage rates. (Grunwald 1985)

Will the increased automation cut down on offshore assembly? So far the evidence is contradictory. On the one hand, it has meant the return of some manufacturing to the United States, while on the other, the $ 9.5 billion value of offshore assembly in the developing countries, up from $6.2 billion in 1980 tells us that developing countries are playing an increasingly important role in assembly and manufacturing of many goods including electrical and electronics products.

But reverse examples exist. The main motivations for repatriation have been the desire to reduce inventory and transportation costs in addition to moving production closer to the end market in order to be more responsive to customers, and in particular, to meet delivery deadlines without maintaining costly inventories.

But, when the US firms automate, then developing countries may suffer the direct loss of jobs and revenues associated with the automated sevtors and processes. Right now, manual assembly is the least cost alternative in the Mexican case, but FMS technologies in particular are gaining ground for a

Table. 7. The development of offshore investment in various third world locations by major Japanese, United States and Western European semiconductor firms 1971 - 1979 (Ernst)

	1971	1974	1976	1979
Asia				
Hong Kong	1	6	6	7
Indonesia	0	3	3	3
Malaysia	0-2	11-13	13-14	4
Philippines	0	0	1	7
Korea	6	8	8	8
Singapore	9	10	12	13
Taiwan	3	3	6	8
Thailand	0	0	1	1
Latin America				
Barbados	0	0	0	1
Brazi	1	0-2	2-5	8
El Salvador	0	1	1	1
Mexico	0	0	12	13
Puerto Rico	0	0	2	3
Mediterranean area				
Malta	0	0	1	1
Morocco	0	0	1	1
Portugal	0	0	2-3	3

wide variety of products. It is important to recognize that the industries of the future will have different staffing and manpower requirements than did the factories of the past and that they may not be significant generators of employment. Nevertheless, they may be important sources of revenue and provide for domestic production of goods.

NICs face a serious dilemma. If they fail to keep pace with new manufacturing technologies they risk failing even further behind, and in the absence of stringent protectionist policies, may lose domestic and export markets to more efficient competitors. But automating requires substantial capital and expertise and may displace labor.

It should be notified, however, that cheap labor is by no means the only important factor when thinking about the MNCs location of offshore assembly. Location of production sites involves a more complex decision making situation, and the outcome is quite irreversible. Decisions for relocation are not made on daily basis. This means, that the changes of prevailing patterns cannot be very quick.

Many of the most succesful MNC production sites in LDCs have in fact developed into rather complex entities with many tight contacts - productional, cultural and market wise - to the local and regional environment. This connection is not so easy to cut. It does not, for example, seem likely that many MNC production sites in the most developed NICs would have remained as isolated islands of low cost labor assembly. Many complex connections to the local and national environment on other levels are involved into the picture.

The locational decisions also depend on the governmental policies towards foreign capital and production in the respective countries. The policies vary in different LDCs. While some countries - for example Hong Kong and Singapore earlier -, have been very open to MNCs, others have restricted foreign industrial acitivities to special 'free zones' or within a definite scope of industrial branches. Countries even more negative to operations of foreign capital exist - also among market economies.

Some countries have tried to connect the locally operating foreign firms more directly to the national development programs, while others have counted more on the direct employment effects caused by the foreign production sites. It remains an open question, what kind of development strategies are connected to these differing policies. Countries with modest resources, however, usually have less negotiation power and are not very likely to be able to set many conditions on the operations of MNCs.

This may imply, that the so called 'second tier NICs' and the least developed countries do in the future have even darker prospects. For them, cheap labor is still the only asset to offer MNCs - the prevailing MNC assembly sites there are either few or culturally isolated from the surroundings. If connections to the local industrial environment are very few, it becomes easier to relocate establishments when the comparative advantages of alternative production sites change.

2.4. The question of manpower

Low cost labor has for long been the main asset of many LDCs. But with the developing technologies and changing industrial structures, the enhancement of skill structure is becoming more and more acute. To approach the question of manpower changes in LDCs, we have to do a brief survey on the general developments in labor force.

Table 8: The share of professional and industrial occupations in some countries (Unesco 1986)

Country	Occupation, % 0-1	7-9	total, millions
Mexico (80)	6.6	21.8	22.1
USA (85)	14.8	28.4	117.2
India (81)	2.9	13.9	244.6
Japan (85)	9.0	36.1	59.6
Korea, rep (85)	5.6	29.0	15.6
Philippines (85)	5.4	18.7	21.6
Singapore (85)	10.0	34.8	1.2
France (82)	14.1	30.9	23.8
FRG (84)	13.9	31.8	28.8
Sweden (85)	29.6	28.7	4.4
UK (81)	15.9	30.7	26.0

Occupational Groups:
0-1 Professional, technical & related workers.
7-9 Prod./related workers, transport equipment operators & laborers.

In developed countries the economically active population has been already for some time decreasing in manufacturing occupations (7-9) and increasing in professional occupations (0/1). In LDCs both figures have been increasing, and in for example Korea and Singapore the share of economically active population in manufacturing occupations is at about the same level than in old industrial countries. The same tendency can also be found regarding paid employment.

From the angle of technological change and strengthening domestic R&D, the share of employment in professional and technical occupations is more important. In this category the figures for developing countries are much worse. Even the most developed NICs seem to be lacking far behind of for example the average West European level. Anyway, some NICs do have good possibilities of changing the situations. Singapore has the best figures, and if we take in account the impressive efforts of building up higher education in software skills, the occupational structure there may in near future resemble the West European.

On the other edge, the share of professionals and technical occupations is very small in India. Because of the huge population in the country, it will take long to change of the occupational structure. For the same reason, however, the absolute number of this group is not so modest in India - over 7 millions.

The occupational change connected to the diffusion of flexible manufacturing automation is not, of course, evident beforehand. According to long term occupational forecasts in USA (table 9) the demand for engineers, computer scientists, technicians, mechanics, repairers, installers, upper-level managers technical sales and service personnel is likely to rise, while the demand for craft workers, operatives and laborers is about to fall. Especially the least skilled labor doing routine work will fall. And because of the change from hardware to software also drafters and programmers will fall (OTA 84). Trends pointing towards same directions have been discovered in many other industrialized countries, too.

Table 9: Long term direction of change in selected occupations sensitive for programmable automation in USA (OTA 1984)

Occupation	Direction change
Engineers	+
Engineering and science technicians	+
Drafters	-
NC tool programers	-
Computer programers	-
Computer system analysts	+
Adult education teachers	+
Managers, officials, and proprietors	?
Craft and related workers	-
Electricians	+
Maintanence mechanistsand repairers	+
Machinists, tool and die makers	-
Inspectors and testers	-
Operatives	-
Nonfarm laborers	-

Table 10: The ratios of attainment and enrollment to post-secondary education in some countries, %. (ibid.)

Country	Attainment (25 years +)	Enrollment (20-24 years)
Mexico (80,83)	4.9	15.2
USA (81,84)	32.2	57.3
Brazil (80,83)	5.0	11.3
China (84,84)	1.0	1.4
Hong Kong (81,84)	7.1	12.8
India (81,75)	2.5	8.6
Japan (80,84)	14.3	29.6
Korea (80,84)	8.9	26.1
Philipp. (80,82)	15.2	29.1
Singapore (80,83)	3.4	11.8
Finland (80,84)	11.9	30.6
France (...,83)	...	26.8
FRG (...,84)	...	29.1
Sweden (79,84)	15.4	38.2
UK (76,83)	11.0	20.3
Yugoslavia (81,83)	6.8	20.2

From the angle of LDCs the change from hardware to software is desirable, because their possibilities to reach the technological frontier by means of science-based learning within their own educational system are quite modest. Policy measures pointing to the direction of getting advance from this situation are also to be seen in some countries, Singapore above others.

Figures for attainment and enrollment ratio in post-secondary education can be taken as indicators for showing the educational level of population and the direction of change in the educational structure.

It is, however, difficult to draw very strict conclusions on basis of these figures because of different educational systems and statistical fallacies. For these reasons, attainment in post- secondary education shows great variation even among the developed countries. To a lesser extent, this is also to be seen in enrollment ratios.

Regarding the future development of the educational structure, the picture seems quite complicated for LDCs. The high enrollment ratios imply, that Korea and Philippines might be able to reach the level of developed countries. For the biggest LDCs, China and India this does not seem to be possible. In Mexico and Brazil the situation is quite uncertain.

2.5. Finance to R&D

Domestic R&D is another important issue from the point of view of developing manufacturing technologies and the industrial structure. Some indicators showing the level and development of R&D investments in a few developed countries and the most important LDCs are collected into table 11.

If measured as a precentage of GDP, the share of R&D investments is usually much higher in the developed countries than in LDCs. However, in

Table 11: Selected indicators for expenditure for research and experimental development (R&D)

Country	% GDP	Per capita (USA=100)	Per R&D person (USA=100)
USA (83)	2.7	100	100
Brasil (82)	0.6	1	14
India (82)	0.7	1	...
Japan (83)	2.6	68	50
South Korea (83)	1.1	5	21
Philippines (82)	0.2	1	10
Singapore (81)	0.3	5	44
Finland (84)	1.5	43	59
France ((79)	1.8	29	66
FRG (81)	2.5	65	97
Sweden (83)	2.6	76	103
UK (81)	2.3	44	...
Yugoslavia (81)	0.8	2	7

France and Finland the share is smaller than in other industrialized countries and only a little higher than in South Korea. On the other hand, in most LDCs the share is still very modest or insignificant.

When compared to USA, the rankings between countries vary depending on the method. According to R&D expenditure per capita USA is clearly number one, Sweden second followed by Japan and FRG. The LDCs with huge populations are very far from the the developed countries.

The list looks different when the ranking is made according to the expenditure per person active in R&D (scientist or engineer). Now Sweden, USA and FRG are first at about the same level, followed by France and Finland as second, Japan and Sinpapore third. In this list the position of most LDCs also gets much better.

Finance for R&D can come from government funds or from private enterprises and specific funds - foreign or domestic - or from both types of sources (see table 12). Examples with the bias on the first type are India and Philippines, of the second Japan and Korea. USA can serve as a typical example of mixed financing. In rule, both sources of funds are relevant in developed countries.

Foreign funds are significant not only in LDCs but also in some developed countries like UK and France. It is quite interesting to notice, that structure of sources for R&D expenditure is almost exactly alike in Japan and South Korea: a quarter from government and three quarters from private sources, no foreign or 'other', unclassifiable funds. 'Other' funds, on the other hand, are rather important in Yugoslavia and Brazil.

In the near future, the governments of Brazil and Mexico may have considerable difficulties in financing R&D, mainly because of the high accumulation of debts. To a lesser less extend this may cause problem for countries like Philippines and Yugoslavia, too. When foreign debts are that high, governments are not very attracted to take more. This might have two important implications. First, other sources than official are

Table 12: Total expenditure for the performance of R&D by source of funds, %

Country	Govern. funds	Prod.ent.& spec.funds	Foreign funds	Other funds	All
USA (83)	46.9	49.6	-	3.5	100.0
Brazil (82)	66.9	19.8	5.3	8.1	100.0
India (82)	86.1	13.9	-	-	100.0
Japan (83)	24.0	75.9	0.1	-	100.0
Korea (83)	27.3	72.5	0.2	-	100.0
Philipp.(82)	76.8	14.9	7.6	0.6	100.0
Singap. (78)	37.6	55.9	5.2	1.3	100.0
Finland (83)	42.3	55.6	0.9	1.2	100.0
FRG (81)	41.3	57.0	0.9	0.8	100.0
Sweden (83)	39.3	59.0	1.5	0.2	100.0
France (79)	51.2	42.9	5.2	0.6	100.0
UK (81)	47.7	42.7	6.9	2.6	100.0
Yugoslav. (81)	31.8	57.2	1.8	9.3	100.0

likely to rise their share in financing R&D; and second, the total expenditure in R&D will increase slower than so far and than in other countries.

In developed countries, the productive sector is responsible for about 60-70 % of all R&D activities measured in costs. The figure is biggest for USA, and exceptionally low for LDCs like Philippines, India and Brazil. The share of higher education sector is at the level of 10-20 %. The figure is highest for Sweden and Singapore, and lowest for India, Philippines and Korea.

Table 13: R&D expenditures by sector of performance in some countries

Country	Sector of performance[1)] Productive sector	Higher education	General service	All
USA (83)	73.0	12.2	14.9	100
Brazil (82)	30.1	16.5	53.4	100
India (82)	*24.7	*3.3	*72.0	100
Japan (83)	64.8	23.0	12.2	100
Korea (83)	60.4	10.3	29.2	100
Philipp.(82)	*9.8	*10.6	*79.7	100
Singap. (81)	54.2	30.0	15.8	100
Finland (83)	60.3	19.4	20.4	100
France (79)	61.3	15.5	23.2	100
FRG (81)	68.3	16.8	14.8	100
Sweden (83)	64.5	30.2	5.3	100
UK (78)	64.1	10.6	25.3	100
Yugoslavia (81)	56.4	18.9	24.6	100

Table 14. Expenditure for R&D per R&D scientist and engineer by sector of performance in some countries.

Country	Productive sector	Higher education	General service
USA (83)	100	90	117
India (82)	100	13	132
Japan (83)	100	65	122
Korea (83)	100	21	93
Philippines (82)	100	67	
Singapore (81)	100	152	42
Finland (83)	100	57	64
France (79)	100	71	86
FRG (81)	100	81	94
Sweden (83)	100	98	72
UK (78)	100	150	
Yugoslavia (81)	100	47	73

The general service sector seems to be strong in countries, where the productive sector is weak - like India, Philippines and Brazil. However, the distinction between higher education sector and general service sector is not very clear. For example in the Nordic countries the educational system is almost completely public.

The average expenditure for R&D by sector of performance varies from country to country. In India, Japan, USA and UK the average expenditure is highest in general service sector, in Singapore in higher education sector, and in other countries in productive sector. In LDCs the differences between sectors are much clearer than in developed countries. Extreme examples of uneven average expenditures between sectors are India, Korea and Singapore. In the two first the figure for higher education is exceptionally low and in Singapore extremely high.

The actual number of scientists and engineers in R&D as a share of population is clearly largest in Japan. If we add the R&D potential - manpower with necessary qualifications for R&D scientists and engineers - into the consideration, Japans performance does not seem likely to weaken. The strong position is an outcome of a long term educational policy.

On the other hand, the potential R&D manpower in Japan is not as concentrated to R&D as it is in Korea or USA, which are the extreme examples. The figure for Japan is at about the same level as for other

***

[1] definitions for table 13:
- **Productive sector** - 'the industrial and trading establisments which produce and distribute goods and services for sale'.
- **Higher education sector** - 'establishments of education at third level including research institutes serving them'.
- **General service sector** - 'various public or government establisments serving the community as a whole'.

* Estimate

Table 15: Scientists and engineers in R&D as per cent of potential scientists and engineers

Country	Actually per million pop.	Potentially per million pop.	Act. as % of pot.
USA (83)	3 111	14 777	21
Argentina (82)	360	18 970	2
Brazil (82)	256	11 231	2
China (84)	..	7 129	..
Hong Kong (81)	..	19 137	..
India (82)	131	2 829	5
Japan (84)	4 436	59 636	7
Korea (83)	801	2 486	33
Philipp.(82)	101	..	..
Singapore (81)	296	15 846	2
Austria (81)	894	20 506	4
Finland (83)	2 265	35 789	6
France (79)	1 364	23 747	6
FRG (81)	2 084	37 001	6
Sweden (83)	2 292	40 597	6
UK (78)	1 545	..	..
Yugoslavia (81)	1 109	17 918	6

developed countries. The concentration level is surprisingly low in Singapore, only 2 % of potential scientists and engineers are actually working in R&D.

However, it is not at all evident, that a high concentration of scientifically educated persons in R&D occupations is necessarily the most productive setting from the point of view of industrial development. Their skills are also needed in productional, commercial, managerial and educational occupations. Focusing on these functions may explain e.g. the exceptional case of Singapore.

2.6. Conclusions on industrial development in LDCs

Success in economic development through the last twenty years is obviously dividing LDCs into two groups. The first group is approaching developed countries, and even in quite many industrial fields. For the second group, the gap towards industrializad countries seems to be widening quite hopelessly. Difficulties met by countries in the second group are often multiplied because of growing burden of debt.

However, a change in favor of Japan in the banking world may open some new possibilities to some LDCs with keen economic relations to Japan. Within the group of LDCs with tighter connections to the USA, the threat of debtors' cartel is likely to give debtors some extra policy options.

Because of a long term educational policy some LDCs are reaching the educational level of DCs by the end of this century. In most LDCs manpower in occupations, which are interesting from the point of flexible manufacturing will be weak for a long time ahead. In some big LDCs the general skill-level is quite static.

The sources for financing R&D in LDCs are quite twofold. Small far east NICs seem to rely on private sector, while the others are counting more on governmental funds. Accordingly the expenditure for R&D will mainly be spent either within the productive sector or wihtin the general service sector. The share of higher education sector is usually very small in LDCs. Also the average costs of R&D are usually smallest in the higher education sector.

Although the figures for R&D for most LDCs are not very favorable, there is already a large potential of scientists and engineers able to accomplish R&D. This far only the Repuclic of seems to have utilized this reserve effectively.

3. COMPARATIVE ADVANTAGE IN LDCS AND FLEXIBLE MANUFACTURING

Most prevailing economic theories of foreign trade are based on the concept of comparative advantage. Comparative advantage is commonly expressed in terms of factor proportions as an explanation for international trade. By specializing into industries with the "best" factor endowments, a country can maximize its utility in the world trade. According to the Heckscher-Ohlin theory, the international competitiveness of industries is largely determined by the principle of relative rather than absolute efficiency (Heckscher 1919, Ohlin 1933).

The concept of comparative advantage can be approached from two angles, the positive and the normative. As a positive concept, it can be used to explain the specialization of production and trade - to explain how the things are. As a normative concept, it can be used as a quideline for government policies on resource allocation and trade - to outline what should be done in order to reach a target.

When investigating the possibilities of LDCs getting advantage of flexible automation, we are primarily interested in comparative advantage as a normative consept. There are two main reasons. First, comparative advantage as a positive concept is getting weaker year by year. The information included in market prices is not, in the long run, comprehensive enough. When focusing on flexible automation, it is necessary to endogenize technology and productivity. Second, it is difficult to find LDCs, where steady state could be regarded as a positive development target. For most LDCs, a dynamic process of economic growth and development is quite simply a necessity.

From this point of view, the important question is, how the structure of comparative advantages could be changed in the long run, and how the physical and human power should be used in order to get advantage of flexible automation and CIM. And, conversely, to reveal where the old comparative advantages could be so strong that they might be taken as a base of new development without a reorientation to new industrial production modes.

In the following a brief survey into the three approaches to comparative advantage in manufacturing given by economic theory is followed by some consideratins on the possibilities attached in factor endowments in physical and human capital.

3.1. Three approaches to comparative advantage

In the economic theory, three main approaches to comparative advantage can be found:

- o the static approach common in textbooks of economics
- o approach oriented to dynamic growth and the process of industrialization (Bruno 1970),
- o and the industry spesific sequential approach (Cline 1982).

Besides these the concept could be approached from quite a few other angles, for example from those of the dynamic advantages, adaptation advantages, cooperation advantages and of cumulative effects. (Kozma 1982). However, from the normative point of view the division into three approaches seems to be the most useful one.

In the static approach, the factor proportions and comparative advantages over time are given. Countries, you could say, have their static, by comparative advantages predetermined places in the global division of labor.

The dynamic - or quasi dynamic - approach is based on a theory of different stages of development. The first stages are often seen as periods of interdependent processes of economic growth within the economy, largely independent of the international environment and often aided by different measures of protection. These measures cause distortions in factor prices and changes in factor supplies, which in time support the development of economies of scale in the production of commodities. In a way, the comparative advantages are let to develop with the aid of general - not targeted - support measures. In the later stages of development the economy can turn to more open international relations now based on the fully developed relative advantages.

According to the third approach, the domestic industrial development is regarded within the context of international economic environment, but in difference to the second approach in a quite selective way. The comparative advantages are actually created and shaped by measures of protection and support targeted on some industries chosen beforehand. In this approach, the role of active governmental industrial policy is very important.

When promoting growth and strengthening international competitivenes are major goals for industrial policy in a country with modest industrial showing, the need for intervention seems to be quite considerable. In LDCs the industrialization strategies are strongly influenced by the position the country is already taking within the international economy. An implication of this is, that the prevailing comparative advantages are important starting points for formulating policy measures, and that a renewal - or even a recreation - of advantages is a central target for policy consideration.

3.2. Import substitution or export orientation?

Depending on the strategy adopted, comparative advantage criteria can be regarded as a guideline for export oriented policy, or as a constraint for import substitution policy. These policy orientations can also be seen as different stages in the process of industrialization: first import substitution when attempting to reduce dependence on imports, and then export orientation when trying to earn from exports and become integrated into the world trading system. Although, substitution of imports by domestic production and expansion of exports are often likely to take place simultaneously.

Among the reasons for promoting domestic production in favor of imports in LDCs, was the decline in earnings from exports which in turn led to decline in imports of industrial goods. This has been the case particularly in Latin America. Theoretically, these actions were based on "elasticity pessimism", according to which both export and import demand are inelastic in the short run (Nurkse 1959).

Typical instruments used for import substitution are tariffs, quantitative import restrictions and multiple exchange rates. A common policy rationale behind these measures is the protection of industries in their initial phases to make them internationally competitive in the long run. The fostering of "infant industries" may, however, cause distortions in the structure of manufacturing industries (UNIDO 1986).

In fact, a new era in export promoting policies began in the 1960's. Success achieved in a number of trade liberalization negotiations raised new optimism also in LDCs (Viner 1953, Haberler 1959). In many countries these international developments and limitations revealed in the prevailing import substitution strategies changed the focus of industrialization policies towards export promotion.

By contrast to import substitution policies, export orientation led to a liberalization of imports. Incentives to promote exports often take the form of - direct or undirect - subsidies and corrections of exchange rates.

In the mid 70s, however, the new expectations turned to pessimism when export demand, as a consequence of depressed growth performance of the world economy, were severely depressed. The decline of growth has led to issues of "new protectionism" but now mainly from the developed countries' side.

In figure 1 the effects on demand, supply and price of a product caused by subsidies are compared to those caused by tariffs (Gorden 1974). PP' is the foreign supply curve, DD' is the domestic demand curve and GG' is the supply curve for domestic, import-competing producers. In absence of state intervention, domestic production of OA would take place, while AB, excess of demand over local production is being imported.

A subsidy at the rate of SP/PO will raise the price received by producers, thus inducing them to raise output to the level of OC. For the additional output AC the society has to pay the price AKLC, the area under social marginal cost curve. However, the cost of imports replaced by local production is given by ANLC, the area under marginal cost of imports curve. Difference between the two areas, KNL, represents the gain the society is earning from the subsidy.

The same production or protection effect can be brought about by imposing a tariff at the rate SP/PO. Now there is, however, unlike in the case of subsidy, also a consumption effect resulting from an increase in the consumer prices. At the higher price of OS, consumption falls by BB' resulting in a loss of consumers surplus by B'EQB. Accordingly, the consumers' welfare is reduced with FEQ, which is the cost additional to the use of subsidies, resulting from by-product distortions.

South Korea offers a good example of criticism against the static approach to comparative advantage. According to the theory, technology and productivity are taken as exogenous and unchanging variables. In South Korea, however, the state - rather than assuming given cost curves like PP' and GG' in the figure above, and attempting to minimize by-product distortions - has attempted to reduce costs in order to gain international competitiveness. Under total prohibition of competitive imports the objective of government policy is to shift the GG' curve downwards to the level to make local production internationally competitive.

The major weakness of the diagram, however, is the inability to portray the mechanisms of productivity increase. In South Korea the dynamic effects of instruments facilitating technical and productive change in local firms are more important than the distortion effects, which are central in the static analysis.

Figure 2.2.1.: Quantity of the importable.

Table 16. The share of LDCs of world exports on manufactures: distribution by country groups and by broad product categories, 1963, 1971 and 1980, %.

Country group	Year	Product Category* M	I	N	S	C	O
Developing	1963	3.4	9.4	8.4	9.3	0.9	30.2
countries	1971	4.0	7.5	12.5	8.0	1.6	24.3
and areas	1980	7.0	9.9	17.9	9.1	4.5	24.6
4 major	1963	2.7	4.1	7.5	4.3	0.7	10.2
	1971	3.2	4.0	11.4	3.4	1.4	9.8
	1980	5.6	6.1	14.9	4.7	3.9	10.6
Others	1963	0.7	5.3	0.9	5.0	0.2	20.0
	1971	0.8	3.5	1.1	4.6	0.2	14.5
	1980	1.4	3.8	3.0	4.4	0.6	14.0

* Product categories:
M = Manufactures (SITC 5-8 less 68)
I = Industrially produced goods and intermediates
N = Consumer non-duraples
S = Supplies and intermediates
C = Capital goods and consumer duraples
O = Other manufactures and semimanufactures

In chapter 3 we have already discussed the main issues of industrial development in LDCs since the early 60s. The showing is largely due to a successful application of policies referred above. We found out, too, the somewhat ambigious features in this success. First, the success is concentrated to a few most developed LDCs, the NICs. Second, when the manufacturing industries in LDCs are refarded as a unity (i.e. industrially produced goods and intermediates) the picture is not so obviously positive. Some branches have had advantage of the policies, others have not. In particular the categories of 'other manufactures' and 'semimanufactures' seem to have been going down in the LDCs.

The ambigious result focuses on a central question in the industrializatio n strategies: in what order should the different industries be developed? Given the scarcity of physical and human capital, policy makers have to allocate resources between various industries. The sequential character of industrial development is spesific for every country, which underlines the normative side of comparative advantage. The South Korean case can, once again, be referred to as an example - there is little left from the positive side of comparative advantage. In other words the sequence of industries in which the relative efficiency of a developing country is to be grown is of utmost importance to policy makers aiming to shape the patterns of comparative advantages.

3.3. Changes in comparative advantage

Although the concept of comparative advantage is at least ambigious, it is a relevant basis for policy discussions in order to find out the possible paths for industrial change and success in the international market. It is necessary, however, to know the factor endowments in the countries under research.

When calculating the revealed prefences in several countries UNIDO (1986) summed capital and skill technology to total capital. The results on some LDCs as well as some developed countries regarding the industries most relevant from the FMSM point of view are presented in table 17.. The figures show, that some relevant changes in comparative advantage have taken place in the 1970s in a number of LDCs. The corresponding changes in DCs are quite marginal, and usually not as promising as in some LDCs.

Table 17. Index of revealed comparative advantage (RCA) in some CIM-sensitive industries (UNIDO 1986a)

Country	1981-83	Change	Country	1981-83	Change
USA			**Brazilia**		
SITC 69*	-0.2	0	SITC 69	-1.2	-1.1
SITC 71*	0.8	-0.1	SITC 71	-2.4	-2.0
SITC 72*	0	-0.2	SITC 72	-0.7	+0.9
SITC 73*	-0.3	-0.3	SITC 73	0.6	+1.2
Japan			**Mexico**		
SITC 69	1.4	-0.4	SITC 69	-0.7	+0.3
SITC 71	1.4	+0.9	SITC 71	-1.3	0
SITC 72	2.2	0	SITC 72	-1.2	+0.6
SITC 73	2.8	+0.6	SITC 73	-2.0	-0.5
Finland			**Hong Kong**		
SITC 69	0.2	+0.8	SITC 69	-0.4	-0.7
SITC 71	-0.3	+0.5	SITC 71	-0.4	+0.1
SITC 72	-0.2	+0.5	SITC 72	-0.5	-0.3
SITC 73	0	+0.5	SITC 73	-0.3	+0.1
France			**India**		
SITC 69	0.3	+0.2	SITC 69	0.7	+0.2
SITC 71	0	+0.1	SITC 71	-0.7	+0.6
SITC 72	0.1	0	SITC 72	-0.3	+0.5
SITC 73	0.5	-0.2	SITC 73	0.2	0
FRG			**South Korea**		
SITC 69	0.8	-0.2	SITC 69	1.7	+2.6
SITC 71	1.0	-0.3	SITC 71	-0.8	+0.8
SITC 72	0.5	-0.3	SITC 72	0.2	+1.2
SITC 73	1.0	0	SITC 73	0.7	+1.7
Sweden			**Philippines**		
SITC 69	0.3	-0.2	SITC 69	-1.3	+0.2
SITC 71	0.4	0	SITC 71	-1.6	+0.4
SITC 72	0.2	+0.2	SITC 72	-0.9	+0.3
SITC 73	0.8	0	SITC 73	-0.5	+0.6
Yugoslavia			**Singapore**		
SITC 69	0.8	+1.2	SITC 69	-0.7	+0.2
SITC 71	-0.8	+0.6	SITC 71	-0.5	+0.3
SITC 72	0.4	+0.6	SITC 72	0	+0.8
SITC 73	0.2	+0.4	SITC 73	-0.3	+0.2

* SITC 69 = manufactures of metal, N.E.S.
SITC 71 = non-electric machinery
SITC 72 = electrical machinery, apparatus and appliances
SITC 73 = transport equipment

In South Korea calculated comparative advantage has become positive - industry has grown "competitive" - in other industries but non-electric machinery, which however is on the way to become "competitive". In other LDCs the results are ambigious; while industries seem to be going up, some are declining. For instance in Brazil manufactures of metal and non-electric machinery seem to be going down but electrical machinery and transport equipment up. In addition to these, transport equipment industry seems to be already "competitive".

According to these results, comparative advantage for India and Mexico seems to be best in manufactures of metal (electrical, and for India also non-electric machinery, rising), for Singapore in electrical machinery (all the others rising), and for Philippines probably in transport machinery, which is showing quite good figures.

But as mentioned in the chapter above, a static analysis of comparative advantage can only serve as a starting point for a dynamic and sequential analysis. In the next phase of investigation, the development in average labor costs in FMS/CIM-sensitive industries has to be taken into consideration. This is to be done to find out the comparative advantage in labor costs, which is of central meaning when a firm makes locational decisions.

In the 1980s the purchasing power of one US$ in the South East Asian low labor cost countries has decreased. In other words, the manufacture of "CIM sensitive" goods in the fast growing Asian NICs is getting more expensive compared to manufacture in other countries, for instance the developed European countries. This is, indeed, a fact opposing the developments of the previous decades.

Table 18. The change in average labor costs (in US$) per annum in the 1980s in manufacture of fabricated metal products, machinery and equipment (ISIC 38), %

Country	Industries*				
	381	382	383	384	385
Mexico (81-84)	-13	-16	-15	-17	...
Hong Kong (81-84)	1	5	3	4	3
Korea (81-84)**	8	7	8	6	11
Japan (81-84)	2	2	3	2	3
Singapore (81-84)	14	12	17	9	16
Finland (81-84)	-2	-1	-2	-2	-1
France (81-84)	-4	-3	-4	-2	-4
FRG (81-84)	-4	-3	-3	-2	-4
UK (81-84)	-5	-4	-3	-5	-3

* 381 = manufacture of fabricated metal products, except machinery and equipment
382 = manufacture of machinery except electrical
383 = manifacture of electrical machinery apparatus, appliances and supplies
384 = manufacture of transport equipment
385 = manufacture of professional and scientific and measuring and controlling equipment not elsewhere classified, and of phographic and optical goods

** according to average wages

Altough the figures for South Korea are not very representative, it is reasonable to argue, that the average labor costs are rising very rapidly in Singapore and South Korea. This seems to be true especially in manufacture of fabricated metal products (South Korea) and in manufacture of electrical apparatus (Singapore).

From the angle of MNCs with offshore assembly in these NICs, the trend implies an increase in production costs in the short run. The urge to substitute capital for labor is obvious, and the incentive for further operations on this area depends on other advantages offered by the area, and the characteristics of alternative location countries.

According to the latest developments in labor costs, the best alternatives in the near future are likely to be found in Latin American countries like Mexico and - in Europe! Of course, characteristics of labor force, work climate and marketing possibilities must be considered besides wages. In manufacture based on advanced flexible automation technologies, other charasteristics than wages are decisive, as we have already stressed.

Even based on these figures, some changes are to be expected in world trade and industrial locations. They will largely depend on the MNCs location decisions concerning the FMS/CIM sensitive industries. We can speculate on some possible trends:

a) If the offshore plants are to be moved near the market areas, LDCs with poor demand are likely to lose their advantage in adaption and implementation of new technology. These LDCs are usually in an early stage of their industrialization. In these circumstances there is neither much room for export oriented policies. The only possibility left for financing industrial advance is to take loans from richer countries. This kind of dangers seem quite relevant for especially the so called second tier NICs.

b) If offshore industries still prefer low wage level, the expansion of assembly plants in Latin Amercia may be expected.

c) The most developed NICs have already passed the initial phases of industrialization and are quite independent of the actual low wage assembly plants. The multinationals decisions to locate into these countries have already for some time mainly been based on other reasons, which have been discussed in some detail in chapter 3.2.

3.4. Conclusions

As noted above, comparative advantage can not be taken as a central quideline for policy measures or more than a starting point in an investigation. But as a normative concept, it can be useful for planning the sequential development path for industry in a country. From this preliminary study, some conclusions on comparative advantage can already be drawn:

1. Flexible automation is - among other things - **changing the structure of comparative advantage** of countries within the

international division of labor. To be successful in this process, LDCs need to shape their industrial structure of comparative advantage industry by industry, i.e. by sequence. Policies towards export promotion depend on the countrys stage of industrialization, factor endowments and policy measures adopted.

2. When a country is orienting the industrial production mode towards flexible automation, the **role of skills and human capital** is important. Because it is difficult for LDCs to reach the technological frontier developed in DCs, learning by doing should probably be preferred to 'science based' learning in industries not on the highest technological edge, like general machinery industry.

3. Planning an industry and industrial change is a process in which information is gathered stage by stage according strategy adopted. In this process the last phase, **implementation of the new technology** is the most difficult one and from the angle of industrialization often the most important.

4. According to recent statistic surveys, the structure of comparative advantage in industry has **changed more in LDCs than in DCs,** at least in the industries relevant from the point of view of flexible automation. The pattern of change, however, is quite different in various LDCs.

4. TECHNOLOGICAL CHANGE IN PRODUCTION TECHNOLOGIES

'Technological change' in manufacturing technologies can neither be reduced to a homogenous evolution process nor just to the question of introducing various new appliances. There are many kinds of technological change, and the variation of effects in each case is wide. The focus of this chapter is on the overall context of technological change for new flexible manufacturing technology - the new industrial production mode associated with the evolution of this new technological paradigm. In doing this, we must somewhat depart from the LDCs as the target of the study and focus on the core of modern technological change in developed countries.

4.1. Levels of automation

The main interest here is attached to the automation of manufacturing processes. As a starting point we must, however, take a bit wider look on the functions of a manufacturing company. The activities of a modern firm can be separated into three different spheres:

- process of design and engineering:
- process of manufacturing
- sphere of co-ordination (all managerial functions)

Within each sphere a set of discrete activities are carried out. Each of these activities have experienced a degree of automation which involved the substitution of capital for labor even long before the introduction of microelectronics. With the development of technologies based on microelectronics this process has, however, moved onto a new plan. Raphael

Kaplinsky among others has stressed the radical change taking place in the development trends within the functions of a manufacturing enterprise with these new technologies:

> 'Whereas the last three centuries have seen the gradual evolution and specialization of the three spheres of production beginning in small factories and then within large through global production via TNCs, what are we now beginning to witness is the re-emergence of the unitary, undifferentiated firm.' (Kaplinsky 1985)

Automation is now, according to Hoffman (idib.) occuring with different degrees of intensity and rapidity at three levels:

a) Intra-activity automation - automation of individual activities.

b) Intra-sphere automation - integration of individual activities within the same sphere.

c) Inter-sphere automation - activities in separate spheres are integrated together via their common dependence on digital control system.

Intra-activity automation represents the type of development, which has continued for a long time before the introduction of modern techniques for programmable automation. Rigid automation, or mechanization, of mainly simple human operations has been the prevailing trend in technological advantage not only in productive, but also in many other human activities. The use of CAD for draughting in the design sphere, word processing for writing, CNC systems to machine tools etc can be taken as examples for intra activity automation in modern context.

Intra-sphere automation is not very new either. The so called 'Detroit automation' - mass production based on transfer lines and taylorized work tasks filling the holes of mechanically automated process - is obviously an early form of rigid intra sphere automation. But as flexible systems intra-sphere automation has only become possible with the introduction of computerized techniques for programmable automation. Continuing the CAD example, CAD for draughting, detailed design and tool path specification, machining centers to perform several different tasks can be taken as examples.

Along with CAD, the main techniques for flexible intra sphere automation are CNC, FMC, FMU, FMS and other advanced manufacturing systems like automated parts storage and retrieval systems. These techniques of programmable automation form the core of modern manufacture. Most of them are not new as technologies but profitable in economic terms they have become only since the introduction of microelectronics. With this new key technology they also have achieved a new stage of technological maturity.

The actual diffusion of these techiques has so far been quite slow, but accelerating. In the previous chapters we have already noticed the differences among industries. Programmable automation is used in manufacturing of discrete products ranging from bolts to aircraft. Most traditional metalworking fall in this category, although other materials (e.g., plastics, fiber composites, ceramics) are increasingly important

Table 19. Final products Incorporating Parts manufactured by Flexible Manufacturing Systems (Edqvist & Jacobsson 1984)

Final Product	Number of FMS	%
Automobiles & Trucks	27	21
Machine Tools	22	17
Tractors, construction mach.	18	14
Aerospace	9	7
Diesel Engines	6	5
Electric motors	6	5
Pumps, valves and compressors	6	5
Hand tools, electric tools	5	4
Railway machinery	4	3
Office Equipment	4	3
Optical Instruments	3	2
Ship Engines	2	2
Material handling equipment	2	2
Others	2	2
Total	129	100

parts of discrete manufacturing as well. For example, in the early 1980s diffusion of FMS, the most advanced of these techniques, was still modest and concentrated into some branches of metalworking industry (table 19).

Within some other industries like clothing, flexible manufacturing techniques are only at the developmental stage. But, even in most of the worst lagging industries, there are considerable R&D efforts being directed towards the development of FMS.

Because of its ability to perform a variety of tasks, flexible automation is usually associated with batch production. However, it has been extensively used in mass production, and it could in fact be useful in custom production as well.

Inter-sphere automation includes a variety of technologies to integrate different functions of manufacturing process. The most comprehensive concept of inter-sphere automation is that of Computer Integrated Manufacturing. CIM as the most qualified means of programmable automation, is often divided in three categories:

- o computer-aided design (CAD);
- o computer-aided manufacturing (CAM) (e.g., robots, CNC, FMS);
- o computer-aid techniques for management (e.g., management information systems and computer-aided planning) (OTA 1984).

According to (OTA 1984) computerized factories which could run on a day-to-day basis with only few people in management design functions are not yet solved even in laboratories. Most existing inter-sphere automation projects involve a more limited degree of integration. This far only some of these solutions are widely and easily available. Furthest developed are systems for linking CAD to CNC machine tools and FMSs.

4.2. CIM and inter firm relations

From the CIM point of view, inter-firm relationships and linkages between different production sites are almost as important as intra-firm relations. Behind this lies the idea of 'Just in Time Manufacturing', based on Japanese 'Kanban' -concept.

This kind of systemfacture, combination of CIM - or even some more modest flexible manufacturing technologies - and JIT-based inter- firm/inter-production site relations can be seen as the technological core of the factory of the future.

The diffusion of flexible manufacturing technologies in combination with Kanban influenced production philosophies will have wide consequenses on the organization of production within indivicual firms. From the point of view of this study, the fundamental changes occurring at the level of inter-firm relationships are at least as important. These developments involve a combination of automation related changes and organization innovation.

The Japanese automobile industry can offer a representative example. The ultimate goal is to develope a continuous flow production process from steel foundry to customer delivery without reliance on buffers of inventory and with outside component supply fully integrated into production (c.f. Jones 1986). The main features of a Kanban production system are:

o zero inventory with no buffer stocks;

o frequent and reliable (zero defect policy) component delivery;

o maximum advantage taken of FMS at all stages of assembly and in-house component production.

This kind of a production philosophy implies tighter connections between the links of the production chain than the conventional subcontracting system. The most important implications are:

a) Relationships between component suppliers and final product manufacturers are being substantially altered. Suppliers have to be located in relatively close proximity to the point of final assembly - or at least the next step in the production chain.

b) Number of components and component suppliers is reduced and organized hierarchically. While the final product is assembled of fewer component than earlier, the components themselves are often more complex and assembled of numerous subcomponent. A corresponding hierarchy of component suppliers will develop.

c) The number of single component suppliers, especially the share of components imported from suppliers overseas, is expected to drop dramatically. But there is no reason, why 'subchains' within the main production chain could not be situated as far as they used to be.

d) Component suppliers themselves have to adopt FMS technologies and stringent quality control.

e) Assemblers and component suppliers are developing extremely close long term relationships with active collaboration in the earliest stages of design extending to various forms of systems integration.

4.3. The change of technological paradigm

When discussing the new microelectronics technology, professor Freeman and his colleagues at SPRU (Science Policy Research Unit, University of Sussex) are speaking of a change in the **technological system** and in the **technological paradigm**. They argue, that microelectronics is the new key technology which is about to penetrate into the basic principles of technology, economy and even the whole society. The old trajectories of technological development are breaking and will be replased by trajectories profoundly influenced by microelectronics - even in technological fields traditionally quite far from electronics. (Freeman 1984, Dosi 1984).

The change does not only touch the technical apparatus and machines. Above all, the change of paradigm is a change in the **basic philosophy** of industry and economy. The principal ideas of the new paradigm become the new common sense and starting point for all managerial and technological thinking. These changes of the 'technological regime' seem also to be associated with the long term cyclical development of economy, a theme not to be discussed here any further.

In manufacturing industry, the new technological system first became apparent in the rapid rise of electronics. The sector was born within the old electrotechnical industry, but grew gradually with the new innovations - transistors, integrated circuits and microprocessors - more and more independent. With widely applicaple microelectronic circuits, electronics are now penetrating into most other industries; if not as components in products, at least in production processes and information systems within a productive company. Even as an industrial sector, electronics seems to be slowly melting into other bransches: most electronics products are simultaneously complex products of mechanical industry, and most products of mechanical and machine industry comprehend a growing share of electronic components. Mechatronics is a common slogan for this kind of products born out of the integration of mechanics and electronics.

Within industry, technologically new products are naturally the main manifestation of this renewal. But the deeper change within the whole industrial systems is actually taking place in the realm of production technology and organization of productive agents. Only when this new microelectronics based technology has fully penetrated into the production processes and managerial thinking of most industrial branches, we can rightfully speak of a new **mode of development** within industy (Perez, idib.).

The characteristics of this new mode of development are, what many researchers have been looking for when studying the effects of new technology in industry. Trend towards CIM seems to be one of the main features within it. From this angle, manufacturing, diffusion and various ways of applying flexible manufacturing technologies can be regarded as indicators showing the **scope and diffusion** of the new industrial production mode - scope in both terms of industrial sectors and regional areas.

Now we can reformulate the target of the study: it is not only a question of production and use of some technologies in LDCs and the possible changes in the behavior of MNCs. Not only are trajectories in some technologies changing their rate and pace of development, but basis of development, the technological paradigm is changing. This change of paradigm does not affect only the technologically most developed countries. It is a question of the global distribution of this new development mode of industry: what will be the role of countries now labeled as 'less developed' in the future international distribution of labor? In what way will the new production mode diffuse into these countries? How do their cultural, economic and historical characteristics affect the basis concepts ot the new industrial production moder? Will they be lagging far behind the more industrial countries, or even remain as islands of a more ancient form of production?

5. LDCS AND INDUSTRIAL AUTOMATION

Flexible automation is presenting severe challenges to LDCs on various levels. Already implementing automatic stand alone machines is changing the picture of their industrialization process; but in particular the more advanced and integrated automation systems can have a much deeper effect on the relative advantages of LDCs.

On the most general level, as a question of national development, the challenge of flexible automation and CIM consists of many diverse problems. There are some mainly structural problems - or conditions - that are common to **all technical change,** both process and product innovation:

1) The national system for research and development: capabilities for research and development, resources granted to R&D and their focusing, the relations of academic research to industry. It is obvious that the higher the average technological capabilities of the country - and of the potential adopters of new technology - are, the faster the rate of diffusion of new techniques will also be. High technological capabilities include the ability to evaluate the properties of the technology, and use them effectively and possibly improve them (Dosi et al. 1986).

2) The educational system and its capability to produce qualified researchers, engineers, managers and workers needed to plan, implement, develop, repair, maintenance and operate modern technology.

3) National attitudes (both on governmental and policy level, in the companies and among the labor force) to new technologies.

The second group of problems is **spesific to industrial automation,** although related to the more general conditions for technological change stated above. But, in addition they also depend on the industrial structure of the country and the composition of firms, companies and plants in various industrial branches. The problems in introducing new technology to the manufacturing processes could be divided - in hierarchical order according to their demandability - into three types:

1) Problems connected to production, implementation and adaption of **stand alone machines,** diverse automation apparatus & single techniques;

2) Producing and implementing **whole FM-systems,** changes in whole factories and implementing new automated production

3) Change in the **whole production mode** and the institutional/organizational setting of manufacturing, within large companies, intercompany production chains and the whole industrial culture of the country/region.

Further, the problems and perspectives of industrial automation in a country need to be approached from two angles. On one hand is the question of **producing and designing** the apparatus needed for automating production processes. The technology in itself is a necessary condition: there is, however, always the 'make or import'- decision to make. Domestic production of automation technology can offer valuable advantage in implementing and maintenance of modern manufacturing systems.

On the other hand is the **use and adaption** of modern automation. There are diverse ways of implementing new technology, and different countries/companies are not in the same position to approach automation, they do not have the same capabilities and same needs regarding automation.

5.1. Production of manufacturing automation technology in LDCs

The manufacture of equipment for automation is quite modest in most less developed countries. However, the capital goods sector has grown quite substantially particularly in many NICs. Some of them even have a longer tradition in machine tool production and export. But modernizing the sector is another problem. Only a few LDCs so far have had any notable success in manufacturing numerically controlled machine tools (c.f. Chudnovsky 1986).

The machine tool industry moved into the use of CNC technology much earlier than other sectors. Earlier machine tools were relatively mature products with a low pace of technical change. They were precisely the sort of product category, where developing countries are said to stand their best chances of gaining into export markets by building up the necessary capabilities through the learning process (Lall 1980). Now the incorporation of microelectronics into these products adds a whole new dimension to the learning process.

The principles of operation of machinery using microelectronics are simply **not transparent.** The design of the machine is now based on different principles and the operational relationship between different components can no longer be perceived from mere observation and the application of 'seat of the pants' innovativeness. The LDCs are absolutely dependent upon the availability of a pool of adequately trained specialists and sufficient R&D resources. This has implications for the innovation and training policies for LDC firms and government policies in the area of higher education and subsidies to R&D.

Domestic production is by no means absolutely necessary for adapting and using flexible manufacturing technologies. However, it helps a lot in building up the capabilities. And when a country is aiming towards a wider diffusion of more advanced flexible manufacturing, it can not avoid the necessity of some domestic production. The sector not only supplies the economy with the machinery but also provides it with the skills necessary in installation and maintenance of imported equipment in any manufacturing sector. An up to date machine tool industry is further needed for the adaption and development of more complex imported flexible automation systems.

A somewhat thorough investigation into the scope of domestic automation equipment manufacture in the case the countries is a guite necessary issue for a further empiric study. A survey on the present situation and the future prospects of manufacturing advanced automatic equipment includes at least the following topics:

a) The domestic manufacture of various machines and apparatus needed (robots, NC machine tools, transportation mechanisms, precision mechanics etc).

b) Control equipment design and production. For example, are the control units used NC machine tools imported or domestically produced? If domestic, are licensed or even of own design?

c) The software situation; is there remarkable domestic production, or are programmes mainly imported?

d) Design of complete production systems: is there any capability to design and plan flexible manufacturing systems in domestic firms (and/or research institutes) does the country have to rely on import of complete entities?

e) The implementing and setting up of advanced manufacturing systems: are domestic suppliers capable of setting the systems up into the plants of customer firms, or is the help of foreign suppliers needed? What is the role of foreign companies localized in the country?

f) The maintenance of flexible manufacturing equipment: are there any functioning maintenance networks? Are the suppliers or users themselves capable of maintenance?

g) How firm is the interaction between capital equipment supliers and users? What is the share of modern manufacturing equipment produced within companies for internal use?

5.2. Use of manufacturing automation technologies in LDCs

The diffusion of microelectronic technology has been quite rapid within the electronics complex, but much slower than was originally anticipated in many other sectors. Clothing industry is an example: design and other pre-assembly activities have been radically transformed, but the clothing assembly process has been rarely affected yet. In some sectors the diffusion process must be measured in terms of decades.

The uneven process of diffusion of automation in the clothing sector suggests that in some sectors LDCs will enjoy a "breathing space". But this space is likely to diminish as microelectronics penetrate even the most technologically stagnant industries. So the LDCs must use the breathing space to upgrade their product and process technology. In sectors, where the future really lies with microelectronics, firms clearly need to enter into the learning curve as quickly as possible, conceivably in an incremental fashion to start with, in order to stay in a race that must eventually become increasingly intense and based on technological factors father than on straightforward comparative costs.

The digital nature of microelectronics facilitates the attainment of a degree of systems integration not possible with analogue control devices. The economic and technical advantages of integration in turn compels producers and users to pursue the process further. Due to the inherent logic of the technology, the locus of technical change and innovation has increasingly begun to take on a 'systemic' character. Isolated islands of automation are being linked together at progressively higher levels of integration. Whereas standalone applications can be relatively easily absorbed by firms, the movement towards higher degrees of systems integration will necessitate basic changes in the organisation of production, in the social relations of production, in the structure of the firm and in its relations with suppliers and end users.

Difficulties in adapting manufacturing automation technologies are accelerating in a hierarchical order - implementating a single stand alone NC machine represents usually the simplest case, the most difficult one is planning and building up a complete new factory based on modern manufacturing concepts. The problems are hierarchical also from the angle of learning: the experience acquired by both the organization and the work force from stand alone machines and minor flexible systems is usually a necessary condition for implementing larger and more advanced systems. Among the hierarchy of problems are at least:

a) Implementation and use of single techniques: stand alone NC -machines, robots etc.

b) Implementation of complete systems from small FMUs to complex FMSes

c) If the equipment and systems are imported, how much adaptive work is needed by installation? Where does the company get the necessary capabilities and installation support from: the foreign supplier, the importer, some independent outside firm, or does it have to install the apparatus relying on own capabilities?

d) The renewal of old plants is more complicated: there is the decision between a total renewal and a slower process based on module approach (starting with NCs and robots, going to FMUs and FMSes and so on) to make.

e) The founding of greenfield plants based on advanced flexible automation technologies and the principles of CIM.

f) The organizational problems at the process of implementation: are new technologies introduced to the prevailing organizations and the prevailing internal division of labor, or is the labor and production organization renewed simultaneously with the change of manufacturing technologies? Which one is the starting point: the implementing of new technology, or the modernization of the whole production organization?

g) The division of labor adopted with the new production technologies: tayloristic principles, or skill based production? There is an underlying issue connected to this question: what has been the initial target of introduction the new systems - reducing the need of qualified manpower, or some other target (e. g. more flexibility of production process, better quality, shorter turnover times).

h) Problems connected with the maintenance of modern technologies: is the maintenance taken care by a) the user itself, b) the supplying company, c) an independent maintenance firm? What is the division of labor between maintenance work - to the extend maintenance is done within the company - and production work?

i) The development of the production processes: is the implementing company adapting modern techniques as single efforts, or is the company thinking the renewal as a continuous process? When thought as a process, both the productivity and machine utilization usually get better in time even when no further technological changes are introduced. When the change is regarded as a single operation, productivity may worsen in time, when problems of maintenance and work force competence occur.

5.2.1 An example: the diffusion of CAD

CAD, computer aided design, is not directly involved into the production process, but is of utmost importance for the development of flexible manufacturing automation and the new industrial production mode. How could LDCs use CAD in an innovative way to renew the whole production system?

CAD has profound impact on the design function in almost every industrial sector - and even outside industry. In manufacturing when CAD is in use, one of the major obstacles to automation in subsequent stages of production is removed. All the subsequent manufacturing activities can be based on the information generated and stored at the design stage. CAD is a basic **precondition** for flexible systems consisting of various producers and quickly changing models.

Since the late 70s the diffusion of CAD has been quite fast. By mid 1982 there were approximately 10 000 CAD installations in the world, expected to grow to 27 000 in 1986. Not surprisingly, very few of them were in LDC's - according to one study only 32 out of total 8000. Further, most of the CADs studied in LDCs were in subsidiaries of MNCs. Without doubt, there are many more in the domestically owned firms especially in the NICs not reached by the study.

Interest to sell CAD into LDCs has been growing. For example Computervision and some other large US manufacturers have set up distributors in Singapore and Hong Kong to sell systems directly to the expanding market among Asian electronics firms. It seems that CAD in LDCs is yet limited to the NICs and to a few central sectors such as shipbuilding, automobile and component manufacturing, metal works and consultant engineering. Out of six systems installed in Brazil in the last three years, 4 are used by engineering firms and 2 by electronics firms.

The rate of diffusion will probably be well below the potential until capital costs decline - until the suppliers undertake a concerned effort to penetrate markets in the LDCs. Of course, even the problems in association of implementing CAD systems in LDCs are enormous. The lack of software abilities is evidently among the most acute problems. Especially, when the suppliers do not necessarily take any deeper interest in the implementation and adaptation of the systems. To Zaire, for exmaple, one CAD was sold without any software.

Kaplinsky (1982) found out that, CAD systems are likely to diffuse in precisely those sectors where export growth was high in the 1970's and where LDCs plan to specialize in the 1980's. Unequal diffusion between developed and developing countries could erode the international competitive advantage of LDC firms operating in markets where their competitors are using the systems.

This point is important e.g. in clothing industry. CAD applications virtually eliminate the need for highly skilled graders and markers and allow very substantial reductions in materials use. By 1982 more than 700 CAD systems had been sold and nearly 50 % of the cloths produced in the US came from firms using CAD systems. Less than 20 systems were sold in the developing countries, in the Asian NICs and to domestic producers in Latin America. The problem sill be studied further in the concrete context of industrial development in LDCs.

5.3. Policy issues

Hoffman (1986) points out, that policy makers particularly in the poorer LDCs frequently do not recognize the crucial role of technology in the development process. Even when policy statements attesting to its importance have been issued, they are often not backed by the political commitment necessary to see that the policies are implemented effectively. Existing institutions are often either ineffectual or are concerned solely with science. In the latter case there seem to be an assumption that the development of technology will somehow automatically follow from that of science.

Many LDC governments are totally consumed with the short term problems of trying to maintain their countries' integrity under conditions of severe resource constraints. Thus the development of technology policy has, understandably, received little attentions. But it is a mistake to believe, that the severity of the crisis has nothing to do with technological factors.

Hoffman gives an example (ibid): the lack of foreign exchange restricts some governments' ability to import essential inputs, intermediates and spare parts. Because of the lack of these inputs, capacity is underutilized and many plants are virtually closed down. The plants have been established for a number of years ago and do not incorporate very sophisticated technologies. In many cases the spares and intermediates necessary to run the plant could have been produced locally. If the past policy had been directed towards the systematic development of a capability among local firms and the producer enterprise itself, to supply spare parts and inputs, the effects of the crisis would arguably have been somewhat mitigated. Thus what seems to be a problem caused by lack of financial resources, is due to the failure of government and managers responsible for industrial development to effectively accumulate human and technological resources.

The government policies towards technology transfer are usually focused to increase the **productive capacity** as cheaply and quickly as possible. Little effort is put into acquiring **technological capacity** along with the productive capacity. Recipient firms get the hardware and some operators training but they rarely acquire the underlying know how and expertise required to improve and adapt the imported techniques. Many problems arise as a result of this failure to use technology transfer process as a learning mechanism.

Performance efficiency of imported plants often decline over time - whereas in developed countries the performance efficiencies normally increase. The difference between the two situations is caused almost entirely by the lack of an indigenous, in-plant technical change capacity in LDCs. By not striving to maximize the learning component of the transfer process, LDCs are missing enormous opportunities to develop technical change-related capabilities not only to improve the efficiency of existing plants, but to participate in design and engineering, in the local fabrication of plant and equipment and often - particularly in the poorer countries - even to develop managerial capabilities.

However, the governments of less developed countries have adopted a great variety of technology related policy measures in their efforts to industrialize. It is hard to draw any simple conclusions or argue on straight forward causal relations between the actual development and the prevailing policy. Only in a few LDCs have the policies been clearly formulated and documented. This seems to be particularly true regarding the introduction and diffusion of new technology into the countries. The the few policy efforts more coherent concentrate on the development of electronics sector and to a lesser extent on the use of computers and information sector. Singapore, Malaysia and India have some efforts made or planned (Hoffman,ibid.).

It is perhaps only in some of the most successful NICs - Korea, Taiwan, Singapore and a few Latin American countries - where the governments have formulated general long range programs to support technological development.

A further study should carry out a detailed investigation on the technology related policy efforts - e.g. finance and promotion of industrial R&D, programs for technology diffusion - in the case countries. In addition to these there are even some questions of overall policy measures that should be studied in order to understand the technological development in the manufacturing industries of the relative countries. Among these are at least:

a) **Policies towards MNCs** - how have different countries acted in their relations to MNCs? Have foreign companies been invited to the respective country mainly in order to create employment, or are there some other targets involved? The other aims can often be seen in the conditions set - or facilities provided - to MNCs locating their plants in the country.

b) The **role of public sector**. The role of government and public sector seems to vary between the extremes even in countries which show quite similar figures in industrializing success. For example, among the Asian NICs, Korea is one of the most centrally planned and governmentally guided 'market economies' there is, while Adam Smith could have used Hong Kong as a text book example.

c) **Import substitution** and **protection of domestic production** against foreign competitors. Many LDCs have based their industrialization on protection of domestic industries under severe foreign competition and often virtually closing the borders from imports.

d) **Origins of export orientation** and promotion of exports. In some countries, import substitution has gradually given place to more export orientated policies and promotion of export industries. In some others, export industries have been promoted simultaneously with the protection of import substituting manufacture.

e) Other public **policies supporting the building up of infrastructure** for developing technology

5.4. Institutional framework

Technological development can by no means be reduced to policy measures or be explained with the governmental behavior. It is a question of the whole setting, interaction between different actors within the national economy and between the domestic agents and the conditions set by international framework. Or, as formulated by Dosi et al (1986), the diffusion of technology is "the outcome of evolutionary processes whereby the interaction between agents induces changing incentives, selection mechanism and learning processes." Interpreting the technological development and evaluating the future trends in a country is a complex task. It should include a detailed investigation of the **structural** features in the economy and the **behavior** of the involved actors as well as a study on the changes in the international environment. At least the following topics should be indcluded:

a) A survey on the **economic and industrial development** so far: the performance of different industrial sectors, the overall structures of branches and companies (even manufacturing plants), the structure (education and occupational) of labor force and the changes in these structures over time. Even the external relations of different sectors and firms - imports and exports, relationships between domestic and foreign companies.

Most of that information - though not necessarily very recent - is available from public sources. A more detailed investigation should, however, be carried on regarding the production chains (or 'filieres' - see Maillat (1984)) most important from the point of view of flexible manufacturing automation. It is of topmost importance to do a quite thorough investigation on the **linkages of firms** within these production networks.

b) The relations between **labor market parties and their institutional/legal regulation.** This is, in the long run, a very central issue, because it involves the development trends of both labor costs and domestic demand. One of the main arguments against the future development prospects of LDCs - even the foremost NICs - has been, that the development of domestic demand and way of life in these countries is lacking behind the industrial development. On the other hand, rising purchasing power means rising labor costs. However, the diffusion of flexible automation seems to be diminishing the meaning of labor costs anyway. In this situation the danger of losing old relative advantage may not be comparable to the advantages of modernizing the way of life in line with the modernization of production structures. In fact, many 'original' NICs seem to be already moving into this direction.

For a study of the long run development of manufacturing industries and manufacturing technology in LDCs this means the inclusion of a problem field, which by the French regulation theorists has been called the 'wage nexus'(Aglietta 1976 a.o.). This concept covers far more than the mechanism of wage determination. It means studying both the way in which workers work to earn their wage (the organization of **the labor process**) and the pattern of consumption which they are able to maintain by means of their earnings (**the way of life**) (Mjoeset 1985). This includes the wide discussion of the future of fordism - or a 'subfordism' - as the organizational form of industrial society in LDCs while it in the developed countries is being reformed to a 'neo-' or 'postfordistic' form better corresponding the new industrial structures and the new modes of manufacturing production (Hirsch 1986, Roobek 1987, Vuorinen 1987).

c) The organizations and scale of **technological capabilities.** According to Dosi et al. (ibid.), the rate of diffusion of new technologies is quite directly comparable to the average technological capabilities of the country. High technological capabilities also mean the ability to evaluate the properties of the technologies, and use them effectively and possibly even improve them.

For an evaluation of a country's technological capability, it is necessary to do a survey on the scientific and technological infrastructure in the country as well as the industrial R&D in manufacturing corporations (both in domestic corporations and foreign subsidiaries). Even the education system producing scientists and engineers should be reviewed.

The information can be mainly obtained from officially published sources, but more concrete and up-to-date data should be collected directly from the case countries and companies.

5.5. Implementing automation in the company level

Companies thinking about implementing automation technologies into the manufacturing processes face a number of initial difficulties even in the developed countries. The implementation of computerized systems as such is a difficult task, particularly when interfaces with the rest of the organization are numerous. The more complex the systems are, the more experience and skills are needed.

In LDCs, where support from software houses, computer experts and hardware suppliers is scarce, the implementation problems companies are facing multiply. Most severe they are for domestic LDC firms. The implementation problem includes, according to Meredith (1987) and Rosenthal (1984), at least the following factors:

a) **Internal skills.** Advanced manufacturing systems are highly complex, frequently computerized and tremendously expensive. Both extensive experience as well as up-to-date education in such systems seem to be required for successful implementation. This challenges both the knowledge of the oldest manufacturing manager as well as the experience of the youngest.

The barrier of insufficient internal skills is obviously much higher in LDCs, where experience in these systems is factually nonexistent and up-to-date skills are scarce. Consequently, the implementation of large systems at one effort can be practically impossible for domestic LDC firms. It is perhaps only the largest companies, which themselves manufacture NC machines, robots and other automated capital goods, in the most developed NICs that have enough capability to install whole FM-systems at one effort.

b) **Multiplicity of Implementation Paths.** Implementing factory automation entails further difficulties because of the multitude of apparent potential paths available to the firm:

- Starting with NC, going to CAM, then CAD, CAPP and so on;
- starting with computerized manufacturing information; systems and linking engineering data to production to purchasing to sales and further;
- starting with cellular layouts, group technology, and just-in-time (JIT) systems;
- building islands of automation - laser cutters, DNC, robots - and then linking them together in a network;
- moving from existing NC and CNC equipment into FMSs;
- automating the materials flow with guided vehicles, automatic storage, stacker cranes, and then automating the machine tools;
- initiating a totally automated greenfield site.

The decision between implementation paths depends on the concrete situation of the implementor and the characteristics of the technology in question:

- how mature the technology to be implemented is,
- how much experience in automation the firm has,
- who is the supplier of automation apparatus and control systems (the adopter itself, domestic fabricator, importer with experience in custom adaption work, foreign supplier, importer,) and the type of relationships between suppliers and adopters.

The likely success of the chosen automation path depends also on the external surroundings of the firm: the institutional framework and plublic policy in the country and region where the firm is operating.

c) Limiting or Multiplying **Synergy.** A further complication with these technologies is the need to use a building block approach to gain what is often referred to as 'synergy'. That is, adopting one system of technology at an early stage can limit a firms options at a later stage. The chosen path of implementation can also have consequences on the future options.

d) Incremental **Skill Building.** The technological skill and experience being gained by their staff must be considered as well: mistakes are an expensive way to gather experience. Therefore, moving slowly and deliberately will often pay dividends in the end. Since the power of these technologies lies primarily in their ability to be integrated into large, complex systems that automatically interrelate with minimal human intervention, the staff must have the vision gained from experience, to anticipate where problems of benefits can occur when the system is extended.

LDC firms do not usually have any abundant supplies of skilled and experienced staff. In many LDCs, the subsidiaries of multinationals seem to be valuable sources of experienced key personnel for local firms.

e) **Support infrastructure within firms.** These technologies require an infrastructure of supporting policies, systems and procedures considerably different from what exists in most firms today. For example - no longer will castings with sand or blowholes be acceptable in raw materials as they were in the past, when workers, trying to expedite an order, welded the defective spots instead of returning the castings to the vendor's foundry. But even more extensive changes will apparently be required. One effect is, that maintenance is expected to assume a much more important role, direct labor hours will be less appropriate for allocating factory overhead, middle management and support staff will shrink in numbers and quality control personnel are expected to have considerably different responsibilities.

f) **Support infrastructure within firm networks.** In developed countries flexible automation is increasingly a question of a wide modernization of interrelations between many firms, manufacturing as well as non manufacturing. The process of introducing flexible automation should in most cases comprehend the whole **production chain** - or 'filiere' (c.f. Maillat 1982), if we think of all the side and support functions needed as well. These **filieres** should also include the supportive agents needed to assist the adaption of modern manufacturing technology. Even subcontractors are often tightly bound within the process of comprehensive technological change.

In LDCs advanced technologies are usually either imported as turn key packages, or manufactured, installed, adopted and used within one large corporation - even though often with various and severe fallacies (c.f. Baark & Jameson 1986, Fransman 1986). This is reality even in the most advanced NICs (see also Westphal & al 1985).

g) **Need for a planned process** on all the four basic stages:

o Strategic Planning: the formulation of the strategic business plan of the firm and the selection of technologies on the basis of firms' competitive strategy - not just immediate financial return.

o) Project Planning: the planning of project structure fot the implenetation process.

o) Installation: the acquiring and allocation of project resources for the task elements.

o) Integration: the inclusion of of automation into the ongoing manufacturing activities of the firm.

Meredith also stresses the importance of an assessment analysis, which should be performed before or within stage 1. The task of the analysis is to determine whether the firm can automate efficiently. There are two major sets of aspects involved - the technological and the organizational:

The **organizational** aspects deal with the "personality" of the firm, its culture, how it operates, what it values and so on. The major aspects are:

- Top management involvement.

- Employee anticipation.

- History of Change: past change in the workplace should have been smooth rather than troublesome.

- Normal functioning: the daily operations of the firm should normally be carried out in a planned, thoughtful way rather than in a crisis mode.

The **technical** aspects should be assessed at the top and the middle level of the firm. At the **top level** there should be a regular evaluation of the factors required to succeed in the firms' markets. The firm should know, what the competitive task is for that market, how it changes, and how, when and why it will change again. At the **middle level,** an important consideration is the current level of automation in the firm. A company used to automation is much more likely to be successful implementing another automation project. The proper functioning of managerial system is another factor at this level. This includes both the formal and informal systems, the computerized as well as noncomputerized systems.

Need for a thoroughly planned process of implementation may even be more urgent in a LDC firm than in a firm operating in a developed country. It is not, however, self evident that the process should always follow the guidelines formulated by Meredith above. The national and regional features may have deep going effects and add new paths to the process. These - national, regional, cultural and company wise - aspects are the ones that should be studied and compared in an empiric survey.

5.6 Conclusions: main problems of flexible automation in LDCs

The possibilities of LDCs to get advantage in CIM are seen in two opposing ways. The pessimistic view rests on the enormous gulf between the levels of economic, technological, political and social developments in the North and the South. Developed countries can be seen embarking on a new and accelerating path of expansion because of their capacity to adjust in time to the rigorous demands of the new technological paradigm. The constraints under which most LDCs operate suggest that they could be left behind.

The optimistic one stems from a perception that the current period is one of tremendous flux and flexibility as well as of crisis. The new paradigm is still very much in its infancy. The old rules of the game are in the process of being thrown away and a search for new solutions involving a much broader range of participants is underway. LDCs should continue to seek to reform the international institutional systems, particularly those associated with technology transfer. They must themselves undertake fundamental internal reforms. The relative malleability of the current situation may afford them better prospects to do so than at any other time in the last thirty years.

South-South trade is one possibility. It has grown quite considerably in recent years, and is important in certain sectors. The environmental conditions, infrastructure and factor price relations are somewhat similar in LDCs. For this reason products successfully designed by local producers for local markets in one LDC will could find export markets in other LDCs too, particularly in the same region. These advantages may now have to be more systematically cultivated. The good prospects seem to, however, be valid mostly to the NICs and some of the countries next in line. The situation is considerably worse and the options remain ill-defined for the poorer countries.

There is a need for new policies. A clear and explicit set of active innovation policies that will require a broad range of inevitably expensive and controversial interventions on the part of governments is needed. There is also a need for fundamental changes in the social and institutional relations which govern the actions and interactions of groups both within the economy and the international level.

The need for deeper going structural changes seems to be quite acute in many LDCs. Major innovations usually concentrate on key sectors and give rise to problems of structural adjustment between sectors. The process of diffusion of innovations is a cyclical phenomenon that starts slowly but moves into a rapid growth phase. This swarming process has extremely powerful multiplier effects on capital goods, components and downstream innovations which give rise to expansionary effects on the whole economy that can lead to long upward swings in growth, output, investment and employment.

But, the ability of different countries actually to succeed will obviously vary widely. And - following such a path constitutes a fundamental normative challenge to the very nature of development in LDCs. The results are only to be seen with a quite thorough and concrete comparative study.

6. THE COUNTRIES

In the following, the discussion on the LDCs industrialization and technological development is carried on on country level. Some areas and countries are taken up as concrete examples. In a further, more detailed survey the investigation should be concentrated to some few countries. The countries chosen for the case study should be:

- at least so industrialized, that the question of introducing flexible manufacturing systems is somewhat realistic;

- neither totally dependant of foreign resources and nor too closed from foreign trade;

- politically and economically so stabile that it is possible to carry out a case study;

Most of these conditions are best filled by the countries usually counted to the so called SICs (Semi-Industrialized Countries) and/or the NICs

(Newly Industrialized Countries). In most statistics, SICs include at least Argentina, Brazil, Colombia, Mexico, Hong Kong, India, Malaysia, Philippines, Singapore, South Korea, Thailand, Egypt and Turkey.

The actual core of NICs is the South East Asian 'Gang of Four': Hong Kong, Taiwan, Singapore and Korea. Into the group are usually also counted Brazil and Mexico from Latin America. In addition to this group, also the rest of the SIC group - often called for second tier NICs - as well as some less developed countries in the European periphery - Greece, Yugoslavia, Ireland and Portugal - are interesting from the angle of industrial transformation and flexible automation. When labor costs are rising in almost all of the ordinary NICs, the offshore manufacturers with low labor benefits in their minds, are turning their interest towards these countries. But they do also have their on industrial targets and aims. Material on concrete development in these countries is, however, not taken up in this paper.

6.1. Latin America

Many countries from Latin America are included to the group of SICs. From the point of view of this study, the most interesting ones seem to be Brazil and Mexico, which both have a reasonably advanced industrial structure. They have also been making efforts to develop their production technologies, both for domestic production and exports. These countries have also been already been subject to a lot of reseach work, which means that comparative material is provided.

Brazil

Brazil is among the largest countries in the world with an industrial labor force over 5 million. The domestic market is quite remarkable.

Table 20. The Distribution of the Value of Manufacturing Output by Industry in Brazil (%) 1962, 1973 and 1980 (Harris)

Industry	Year		
	1962	1973	1980
Traditional Industries	49.2	41.9	34.5
(Food processing, beverages, tocabbo, textiles and garments, footwear, furniture, printing and publishing)			
Non-traditional industries	50.8	58.1	65.5
Metallurgy	10.7	12.2	16.7
Machinery	2.9	7.2	6.4
Chemical Products	9.8	12.1	17.1
Non-metallic minerals	4.3	3.4	4.0
Electrical and telecommunications equipment	4.8	4.9	5.4
Transport equipment	9.6	8.9	7.6
Paper and paper products	2.7	2.8	2.8
Rubber and rubber products	1.9	1.5	1.5
Pharmaceuticals	2.0	2.0	1.2
Perfumery	1.0	1.2	0.9
Plastic products	1.2	1.9	1.9

The time series shows, that the structure of manufacturing industry is already quite modernized. Machine tool production is quite remarkable in Brazil, and so is the general machine manufacturing sector as a whole. From the angle of flexible manufacturing, the large metal manufacturing sectors in Brazil offer an interesting object. Brazil has the largest capital goods producing sector among the LDCs.

According to Erber (1986), the capital goods sector has not been able to play the same role in the dynamics of Brazilian economic development as that industry usually does in the advanced countries. The review on revealed comparative advantage in chapter 3 also showed, that Brazilian exports had changed into a more favourable direction only in the trade of electric machinery and vechicles. In all other products studied, the imports were still overcoming exports.

The country has encountered various problems, among which the high level of foreign debt is one of the most severe. Brazil has, however, been favoured by foreign capital. And the rising debt level has not had any worse effects on foreign firms (Laakkonen 1987).

Mexico

Mexico has a long border common with the US, which makes the country's geopolitical situation quite unique. Short transport distances together with low wages - even 90 % under the US wage level - makes it particularly beneficial for US firms to locate assembly sites into Mexico. This has been further facilitated by the tax free maquiladora -zones in the north of the country, where foreign producers do only have to pay customs for the exported value added, not for importing machines or subassemblies.

The growth of US-maquiladoras has been impressive: from 588 production units in 1982 to almost 900 units in 1986. By the end of 1986, 260 000 workers were employed in these factories. Manufacturing in the maquiladoras has mainly consisted of simple assembly, but in the newer factories computer controlled machines are common and more complex tasks usual. (IU 3.4.1987)

The factories are quite concentrated: 185 (20 %) of them with 85 000 (33 %) workers are situated in Ciudad Juarez. With El Paso in Texas just across the Rio Grande, the location can also offer quite good agglomerations effects.

Japanese and European companies have also shown interest to locate into Mexico lately. For them, a Mexican production site offers a good springboard for the US market. This was admitted also by the representative of the Finnish electronics firms Evox, which has been having its own maquiladora factory in Juares since 1982.

Even the supply of skilled workers seems to be qood in Mexico. The Evox representative mentioned, that the four University Colleges and many technical Colleges in the City of Ciudad supplied all the needed work force.

Table 21. The Distribution of the Value of Manufacturing Output by Industry in Mexico (%) 1950,1960,1970 and 1978 (Harris)

Industry	Year 1950	1960	1970	1978
Food, drink and tobacco	26.4	36.8	29.0	25.8
Textiles garments and leather	26.1	18.8	16.8	16.3
Wood, paper and publishing	10.8	8.1	7.6	7.2
Chemical Products	7.8	11.2	13.5	13.7
Non-metallic minerals	3.5	4.1	4.4	5.4
Basic Metals	4.1	6.2	6.8	8.2
Metal Products	9.3	12.6	19.6	21.3
Other	2.0	2.2	2.3	2.1

6.2. South East Asia

Especially in exports, the South East Asian region has been the most successful area. The 'Gang of Four', as South Korea, Singapore, Hong Kong and Taiwan are often called for, has made a remarkable showing during the last twenty five years. They seem to be following the Japanese path. It may even be confusing to call them 'less developed' any more. Many economic indicators for them are well nearer to the old industrialized countries than the Asian or African LDCs. On the other hand, however, we have in the previous chapters noticed the various fallacies in the industrial structures of these countries and the difficulties they are encountering in their efforts to develop their industrial technologies. In the following, Hong Kong and Singapore are commented briefly and Korea is taken under a more detailed examination in appendix.

Singapore

Singapore is a city state with the smallest population of the four. Between 1965 and 1980 the economy in Singapore grew annually in real terms by 9 %. This was the highest figure among the four. The manufacturing economy in the city is, like in Hong Kong, quite narrow. Five industries - oil refining, electric products, food manufacture, transport equipment and garments - were in the mid 70s' responsible for 66 % of employment and 73 % of manufacturing output.

The city has lately put a strong focus on the development of software capabilities. The country has quite limited work force, and the days of real advantage of cheap labor are far behind. The labor costs have been raising almost as quickly as in Korea. The focus is also in line with the change of the countrys' economic structure, which has grown more service oriented; by the early eighties two thirds of the GDP was generated in the services.

The government of Singapore has also announced a comprehensive set of policies intended to upgrade and diversify the electronics industry. The main targets are (Hoffman, ibid):

a) To concentrate on production of higher quality components.

b) To expand production of Industrial electronics into full devices.

c) To increase the level of automation in consumer electronics.

d) To establish a world class computer services and software industry.

So far the country has had most success in the areas of industrial electronics and computers. Foreign firms have already invested more than US$ 100 million in computer assembly and peripherals production facilities (DE, Apple, Astec etc). Many of these initiatives have been undertaken as joint ventures and involve the extensive use of highly skilled expatriates who bring a good deal of technological sophistication to the project.

The actual long range target is to build up an export-oriented software industry. The elements in the national strategy are:

a) To increase the level of computerization

b) The rapid expansion of computer services and software training and education programme. This is the cornerstone to Singapore's software strategy.

c) Direct promotion of an export oriented software industry.

Shortage of software skills has been identified as the principal constraint to Singapore's ability to achieve its wider electronics sector objectives. An estimated demand of nearly 8000 software professionals was expected to emerge over the eight years from 1983 onwards. The stock in the mentioned year was only 1200 professionals. Previously computer and software professionals came largely from the in-house training programmes of MNC computer vendors and large computer users such as banks and insurance firms,. Now the government has implemented a series of financial/export incentives to stimulate firms to upgrade and expand their training programmes. In addition, five specialist training institutions have been established with an expected annual output of 700 - 1000 software professionals.

The fostering of an export-oriented software industry depends both on the creation of domestic firms and on the attraction of foreign software firms. The government has also created a science park adjacent to the National University, which will house many of these firms as well as the government sponsored Software Technology Center.

Singapore is, of course, in a unique position vis a vis other, particularly poorer, developing countries. Nevertheless there are elements that are instructive such as the diverse range of training and knowledge suppliers that Singapore has attempted to build into its educational strategy. Other LDCs do not possess the advantages of Singapore. However, with the appropriate degree of attention to education, incentives and infrastructure, the creation of a minimum level software capability seems well within the scope of many of them.

What comes to adapting flexible automation into industrial processes, Singapore is perhaps the least interesting one of the 'Gang of Four'. It is trying to focus away from manufacturing industry into software development. On the other hand, higher capabilities in software also offer a lot better starting point for the use of advanced flexible automation in manufacturing processes.

Hong Kong

Hong Kong was, in fact, the first of the four South East Asian countries to begin the process of rapid export led growth. The first US offshore assembly site in the region was grounded there in 1962. Foreign investment is in Hong Kong of much less importance than in Singapore, though more important than in Korea or Taiwan. Only about 10 % of the citys' exports are said to be under foreign control - compared to 20 % of Taiwans', 15 % of Koreas' and 70 % of Singapores' (Harris 1986).

From the policy point of view, Hong Kong offers a text book example of free market development with minimum of government intervention: no economic strategy, no long term planning, no large state investments. Hong Kong's exports have thus been able to show the 'pure' state of world demand. Accordingly, the fluctuations in production and export figures are also remarkable.

Other exceptional conditions have, however, affected the economic development in Hong Kong. The status as an East Asian port for the British Empire guided the early industrialization. Since the late forties, the location in the neighbourhood of China has been particularly important. After the revolution, crowds of both capitalist and skilled workers particularly from the Shanghai region fled to Hong Kong to form the core of textile manufacturing.

Now, the most important manufacturing industries are textiles and garments, electrical machinery and apparatus and plastic goods. These three branches together are responsible for two thirds of the city's exports. The firm structure in Hong Kong resembles that of Taiwan's: the companies are predominantly small or tiny operations, labor intensive and family run.

The survey on revealed comparative advantage above showed, that Hong Kong has not done very well lately. Only non-electric machinery and transport equipment of the for industries studied show positive development, and even it was modest. The low cost labor benefits have also faded little by little, though not as evidently as in the other South East Asian NICs.

All these figures of recent development point, that Hong Kong may be at the edge of a structural transfomration. One very important factor for the future of Hong Kong is the relationship to People's Republic of China, which will take the rule over the city in 1999. Already now, China has the largest stake of foreign investment in Hong Kong. Correspondingly, capital from Hong Kong is most important in China.

6.3. The Big Countries

The two countries with worlds largest population are interesting already for that reason. But other reasons exist. India has a diversified industrial sector and a good supply of educated manpower. In the long rung, there are quite immense resources, both as future markets and production resources, in China. The country has recently also started to concentrate its efforts on strengthening the industrial base and exports.

India

India is a vast country with many faces. It has a reasonably large amount of educated people, and an industrial sector already diversified, growing rapidly and increasingly sophisticated. This progress has been accompanied by rising per capita incomes and growing consumer expectations.

Development of an Electronics Capability

India faces the challenge of developing a diversified electronics industry capable of meeting the continually expanding demand for electronics products, computers and components (Hoffman, ibid.). The Indian Government has been centrally involved in fostering the development of the electronics industry from the start. First via the Electronics committee in the Department of Atomic Energy set up in 1964 and then through the Department of Electronics and the Electronics Commission set up in 1970.

The Indian policy was until 1980/81 primarily oriented towards satisfying domestic demand rather than promoting exports, and towards the development of domestic technological capabilities rather than a reliance on foreign technology. Government involvement took the form of direct participation at the state level in the manufacture and consumption of products and components; and via a variety of short and long term measures devoted to the support of the private sector. The latter measures involved import protection, market reserve policies, export concession, manpower training and the creation of a national network of R&D training and testing centers (18 in all). Foreign involvement in the sector in the 1970s was strictly limited to specified areas.

These efforts led to very respectable growth in output, averaging 19 % per annum during 1973 - 1983. But even this rapid growth was insufficient to meet demand. Imports averaged around 35 % of domestic consumption between 1976 - 1983. Export performance has been more modest, with most of the growth limited to software components and products assembled in the Santa Cruz Export Free Trade Zone.

A Government review identified, however, several major weaknesses in the electronics components sub-sector. The most serious problem was that the country had no facilities to manufacture microprocessors, since even though some 20 plants made semi-conductor devices, about 75 % of the output consisted of discrete devices largely intended for the consumer electronics industry. Total output was very small, quality low and costs high. However, there was some evidence of a vertically integrated production capability for a number of devices where all manufacturing steps were carried out using indigenous technology.

Some growth-oriented measures have been introduced:

1) Fiscal and financial incentives to allow a higher rate of depreciation of components and reduction in import duties on such equipment and on material inputs.

2) A new industrial licensing and foreign collaboration policy was introduced. Technology imports become freely allowed if suitable to establish production capacities on an internationally viable scale.

3) Emphasis on production planning is being given to exports as well as to domestic markets.

4) More public sector supported enterprises have been established. The most important of these is a $ 100 million investment in Semi Conductor Complex Ltd which is to design and manufacture LSI and VLSI devices. Here considerable domestic spin off is hoped for in the consumer products sector as a result of local IC production - digital watches, electric clocks, pen watches, calculators and microcomputers are all expected to drop in price because of cheaper domestic chips, leading in turn to an increase in demand for these products. LSI wafer fabrication was expected to commence in Oct. 1983.

The Government committee also found serious problems in the systems and procedures set up to screen and approve private sector proposals relating to the import of technology, the expansion of capacity and the establishment of new enterprises. This criticism of bureaucratic procedures has much value for other developing countries seeking, at whatever level, to stimulate the development of an electronics sector via state intervention as well.

People's Republic of China

The research done on the technological change in the People's Republic of China is quite modest so far. The country shows, however, increasing industrial power. For example, a remarkable share of manufacture of textiles and garments for exports, which was one of the initial springboards for many NICs has now moved to China.

Table 22. Monthly wages for workers in 1982 (Oborne 1986)

Country	Wage in HK$
Japan	3950
Hong Kong	1356
Singapore	1247
South Korea	1115
Shenzhen SEZ	540
Shantou SEZ	400
Xiamen SEZ	400
Zhuhai SEZ	400
Guangzhou PRC	200
Philippines	197
PRC, average	175

One background factor for this is, evidently, the low level of wages. As table 22 shows, China seems to be quite supreme in this respect. In the East Asian region, only Philippines were compatible in terms of low wage costs in the early 80s.

In the post-Mao period, China has focused on modernizing the industrial sector. With the introduction of so called Spezial Economic Zones (SEZs) in the late 70s, China has also gradually started to open its gates to foreign capital. SEZ seem to be a most interesting experiment to transfer technology and build up cooperation with chinese and foreign capital. The regions are, in fact, a kind of 'islands of capitalism' within the Chinese borders. The four essential 'window' functions of the SEZs are, according to a Chinese document underwritten by Deng Xiaoping himself (Oborne 1986):

a) as a means of absorbing new technologies;

b) as a means of acuquiring information about the world beyond, by using foreign skills and techniques, and as a conduit of information about the international economy towards the rest of China;

c) as a means of observing, and absorbing, new management techniques introduced from abroad. This is done through the co-operative agreements signed in the SEZs, as well as foreign training given to Chinese personnel in the SEZ;

d) the SEZs can also serve as a place where special policies, not destined for the rest of the country, are experimented. They can also be used as means of implementing new foreign policy for the PRC, an 'avant garde' of political thinking in the PRC.

The experience with SEZ so far - though limited yet - has not come up to all expectations. The development of particularly industrial production has been slower than planned, and costs for building up infrastructure has exceeded far over the initial calculations. All SEZ have neither succeeded in attracting foreign capital as much as hoped.

One reason behind this may be the relative isolation of SEZs. The backward linkages into the domestic economy from the export processing zones have been weak in most other countries, and if the SEZz are isolated in the same manner from the domestic economy in China, the same may well occur in there.

The experiment is still to find its most successful forms. It may be, that SEZs will remain quite small, though important centres for Foreign direct investment in China. More importantly, they will act as catalysts for structural economic reforms within the country. For the overall technological and economic development of the country, attracting foreign capital to the cores of Chinese industry, Shanghai and Guangzhou, may be more important. However, in late 1985 there were in total 68 joint ventures with foreign capital operating in the SEZ, and the number is growing steadily.

What comes to the use and production of modern automation technologies, a survey done on the topic in the early 80s did not come up with very couraging results (Baark & Anxian 1985, Baark 1986). The outcome was, that about one third of the apparatus studied had never worked and was neither likely to work ever. The other third was out of order as well, but these were machines that had already been in use, and could, if repared accordingly be put into work again. Only the remaining third of apparatus was working, though not necessarily wery vell.

Different sources of fallacies can be found depending on the source of technology. When the apparatus in question was imported, the main reason for problems was usually the lack of skills to implement them, to operate and maintenance them. The software might also be complety wrong for the purpose, or machine simply unsuitable for the process in question.

Table 23. Country of Origin of Equity joint ventures within the SEZs, to November 1984 (ibid.)

Country	No. of ventures total inv.	Total Foreign investm. US$ mill	%	Country share share in %
Japan	9 (5)	70.6	60.0	26.0
US	8 (5)	58.9	49.6	18.0
Hong Kong	33 (32)	67.7	53.3	22.0
FRG	1 (1)	27.5	50.0	8.4
Singapore	3 (1)	20.0	30.0	3.7
Denmark	1 (1)	5.0	50.0	1.5
Philippines	1 (1)	4.5	51.0	1.4
Switzerland	1 (1)	0.36	50.0	0.1
France	2 (0)	na.	na.	na.
Hong Kong &	3 (2)	50.9	49.3	15.4
Unspesified	4 (2)	1.5	91.0	0.9
Total	68 (53)	314.66	51.5	100.0

When dealing with domestically produced apparatus, which was the more common case, problems could raise from many different sources.Usually, though, the underlying weakness was lack of skills, on many levels. Another reason can be found from the fact, that most of the machines were produced in house. Only prototypes and single copies of machines were produced to just one special purpose. The factories simply could not come up to the quality standards needed in the manufacturing of modern apparatus. Design mistakes were also made, software presented additional problems, and the machines manufactured could never, in fact, be operated in the aimed productive functions.

This fallacies in the production, implementation and operation of flexible automation technologies offer an enormous amount of problems. But when some of them have already been 'tested' by trial and error, the future possibilities may be a lot better.

This is strengthened by the quite strong policy focus on developing modern manufacturing technology. For example the development of industrial robots has been listed as a key project in the on going - the 7th - five year plan. The first development center for robots has been extablished in Shenyang. But already about a hundred different types of fobots have been developed and built in China, though mostly for laboratory use only. The Beijing Research Institute of Automated Machine Building has also manufctured four industrial robots to be used in painting in the Beijing Jeep Company and is producing more. (Teknisk Utblick 7/1987)

China with its large population and eagerness to develop both the domestic standard of living and industrial strength towards exports, is obviously one of the most interesting fields for the study of technological change - also from the point of view of manufacturing technology.

7. A SKETCH FOR AN EMPIRIC STUDY

On basis of this literature survey it is possible to argue, that no trends exist, that would categorically determine the industrial and technological future of LDCs. There is no single 'flexible production mode' that would have undisputed effects in all manufacturing industry and every country. The developments in manufacturing technologies vary according to industrial sectors and products. Every country faces an individual future: it seems likely, that the development paths of different LDCs even are about to **disperse.** Correspondingly, the possibilities for technological and industrial development for a country is connected to the **industrial structures** of production and trade, to the technological and scientific **infrastructure,** and to the **policies** adopted - and above all these, to the characteristics of the **firms** active in the respective country. It is a task of more a concrete, empiric study to investigate the combinations of structures, policy and company behavior, which would lead to success in the changing technological environment.

The future study should continue to define and investigate the questions preliminary formulated in chapter 5. For this task, the study should be organizaed as a comparative study between and within pairs of countries. The pairs should be comparable in terms of their sosio-economic characteristics, stage of industrialization and their outward-looking policies. The structure of comparative advantage in idustry could be taken as a secondary criteria. The following set of pairs is proposed:

(1) Brazil - Mexico
(2) People's Rpeublic of China - India
(3) The Republic of Korea - Taiwan

It would even be interesting to take a couple of countries from the European periphery as a fourth pair. Even a comparison between LDCs on the 'NIC stage of development' and some other recently developed countries could be interesting, too. For this kind of study, Japan and Finland might be the two most interesting examples. Many NICs - Korea and Taiwan typically - seem in many respects to be trying to follow the Japanese development path. Finland, on the other hand, is also a country with a recent history of industrialization: in the 40s' about 50 % of the Finnish labor force was still in the primary industries, and the country has in fact industrialized since the late 50s'. The post industrial stage with declining employment in manufacturing industries and growth in services only is reality since 1981. Now the Finnish industry is eagerly targeting towards more flexible production modes and high technology products.

A three stage study is proposed:

1) A statistical and literature survey on the case countries starting from a more concrete investigation on the changes in the structures of comparative advantage in the industry of case countries.

2) A more empiric study on the industrial, institutional and technological development in the case countries

3) A study in the company level, with
- companies manufacturing flexible automation equipment;
- system importers and suppliers;

- manufacturing firms in different industrial sectors adopting flexible automation technologies;
- and respective firms not adopting, but possible adopters

as empiric cases in the case countries.

The target of the study is to research the effects - the threats and possibilities for new development - of flexible automation for manufacturing industries in the case countries. A further aim is to formulate different paths for development and policy options for LDCs to face the challenge of flexible automation and CIM.

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Appendix: The Case of the Republic of Korea

Korea is considered by some analysts as the only one among the East Asian Gang of Four that has the manufacturing base to produce high-value-added products sufficient to sustain high growth rates over the next decade (Electronic Week May 6, 1985, according to Rushing & Brown 1986). With a population over 40 million it can also lean more on domestic markets than the other three.

The Korean industrial performance so far has been quite outstanding. In 1953, agriculture produced some 47 % and manufacturing under 9 % of the Korean GNP. In 1981 the comparable figures were 16 and 30 %. The shares of labour force are comparable:

Table 1. The Breakdown of labour force between agriculture and manufacture in Korea in 1960 and 1982

Labour force	Agriculture	Manufacturing
1960	66 %	9 %
1982	33 %	20 %

The manufacturing sector has also gone through a transformation: the contribution of heavy and chemical industries to total industrial output, 23 % between 1953 and 1955, was 29 % from 1960 to 1962 and 42 % from 1974 to 1976. The share of engineering industry in the manufacturing value added has risen from under 11 % in 1960 to over 25 % in 1982 (Jacobsson 1986):

Table 2. The share of engineering sector of the Korean manufacturing industry MVA 1960 - 1982

Year	Share, %
1960	10.7
1963	10.2
1966	14.3
1969	14.0
1975	16.3
1979	24.2
1982	25.3

The figures on export are even more impressive. In early sixties, the ratio of exports to GNP was only ca. 4 %. Twenty years later the ratio rose to ca. 40 %. This means, that the growth of exports attained an average rate or 35 % a year from 1962 to 1982. During the same period, the share of manufactured goods in exports rose from under 20 % to over 90 %.

Backgrounds to the Industrialization of Korea

Until 1945 Korea was a part of the Japanese Empire. Tokyo introduced - besides a cruel regime upon Koreans - a modern administration, monetary system, railway network and education. By 1945 about 25 % of population had acquired some formal education. Between 1910 and 1940 manufacturing output increased on average by 10 % per year, and the composittion of manufacturing output also changed - light industry (food and textiles) declined as a proportion of the total from 72 % to 45 between 1926 and 1939. Export was important: about 2/3 of the manufacturing output went overseas, mostly to the rest of the empire. In 1940 there were about a quarter of million Koreans employed in factories, another couple of million Koreans living in Japan and possibly another million in mainly industrial occupations in Manchuria. In fact - Korea seems not to be a particularly 'new' industrial country.

When the war ended, the ruling order in Korea, its business and technical class was removed. Korea lost external markets and raw material imports through the collapse of imperial trading system. Heavy industry and mining remained in the Norh part of the country while the southern administration inherited two thirds of the population, nearly half the arable land, 70 % of rice growing areas and much of the light industrial capacity.

After the Korean war up to 1960 the crippled South Korean economy was supported only by massive American military and civil aid, as well as tight economic controls including protection against imports. Years between 1961 and 1979 was characterized by 'the economic miracle of Korea' and increasing export orientation - which was partly due to the decreasing american aid. Export was not an alternative to import substitution. In 1973 the Government introduced the Heavy Industry and Chemicals Plans.

Since 1979 the government has drawn back its strategy of creating a heavy industry base - which had created a set of uneconomic industries - and obliged to begin measures of liberalization. It was partly an attempt to open Korea to American imports for retaining access to US markets. Pruning was now aimed at concentrating resources on a few key heavy industries (which, however, were not chosen by simple deducations of comparative advantages). The economy had become much more complex than a couple of decades earlier, and according to Harris (1986), it was no longer suspectible to the crude imperatives of public policy. Also the substantial business class evolved during these decades was unwilling to accept governments unilateral definitions of the nations interest. The building of an independent national economy - albeit, of a special export-oriented kind - now had to give way to an increase in the integration of the Korean and the world economies.

Development of single industrial sectors

a) Shipbuilding

In the early 70s the Korean government focused on shipbuilding. The grandeus plans were not all realized because of the oil crisis. Ten years later, the Korean Shipbuilding industry was in severe difficulties, but has now overcome most of them. The most important shipbuilders are Hyundai, Daewoo, Samsung and Korean Shipbuilding. In 1986 Japan built 5.87 million tons of the total of 7.95 million tons of new ships in the world. The South Korean foreign orders were 2.4 million tons, while Japan got only 2.37.

According to the latest statistics, (The Association of Japanese Ship Exporters) Korea has overdone Japan in the first quarterly of 1987 as the largest shipbuilder in the world: Korea got orders 1.04 million tons, Japan for 0.91 millions. The Japanese share of world ship orders (in total 3.44 mt) was 26.5 %, while the Korean share was 30.2%. The corresponding figures a year ago were 50.7 and 9.3 per cent.

In spite of the showing success, work force employment has been reduced: total of 20 000 persons have been reduced in the Korean shipyards, and more reductions are anticipated. It is obvious, that this also means technological advances in the production process. In particularly so, while the scope of activities in the main shipyards has been further widened. They have even started operations outside shipbuilding, building 'oil boring ferries', steel constructions and nuclear power stations.

b) Automobile manufacture

Automobiles have been the latest and most spectaculous achievement of Korean export industries. Even in his book published 1986 Woronoff is still somewhat doubful about the possibilities of Korean car exports:

> "...(the automobile) market never expanded as rapidly as hoped. And exporting was more difficult than eexpected. This left the industry in a tight position that was unlikely to impoprove much before the end of the 1980s." (Woronoff, ibid., p 111.)

However, in 1986 Hyundai exported 160 000 'Excel' cars to the United States (HS 19.7.1987). Three years earlier the Korean car exports to the US reached the total figure of 65 cars. In those days, Korea was the 20th on the list of world car manufacturers, behind for example Argentina, Spain and Poland.

Already in 1984 Hyundai had introduced the 'Pony' into the Canadian market and 80 000 of them were sold in the first year. It passed immediately the Japanese in sales figures and jumped on the top of the list for imported cars (Insinööriuutiset 28.1.1987).

For 1987, the export expectations of Hyundai were 330 000 of the total manufacture of 610 000. All Korean car manufacturers expect to be exportin ca. 680 000 cars, which is 2/3 of the total production. Up to 1990 Korea is counting on a total manufacturing figure of 2.25 million cars.(HS 19.7.1987)

Hyundai started car making in Korea 19 years ago with assembling cars for Ford. When the company wanted to start the manufacture of domestically designed car types, Ford cancelled the cooperation. The Japanese Mitsubishi came in as a new partner, started to subcontract parts and also became a co-owner with a 15 per cent share of the mainly one family owned company.

Two other car manufacturers, Daewoo and Kia, are also aiming at foreign markets. Their export strategies are quite different to Hyundais'. While Hyundai has everywhere built its own sales organizations and is marketing the cars under the companys name, Daewoo and Kia are focusing on joint operations with American companies. Daewoo is partly owned by General Motors, and its 'LeMan' cars will also be sold in the US as Pontiacs. Kia is cooperating with Ford and using the Ford sales organization for its 'Festiva' cars. Daewoos strategy may be the most successful in opposing the protecionistic measures taken by the US government. Hyudai, on the other hand, is trying to cope with them by building an assembly factory in Canada to be operating in 1988.

Daewoo, Hyundai and Kia - which are conglomerates operating in many fields from shipbuilding to electronics - are extremely important for the Korean economy. Only their car manufacturing divisions count for a quarter of the Korean GNP. Their car exports are also responsible for the first time occuring export surplus in the Korean economy. The Korean surplus in trade with the US was ca. $mrd 5,7 in the three first quarters of 1986.

The trade with Japan, however, was almost as much negative as the trade with US positive. The Korean surplus was ca. $mrd -4.6. Technologically the Korean car industry is quite dependant on Japan. Japanese firms are also the most important parts vendors for Korean car manufacturers. Conversely, Japan has kept its market strictly closed to Korean cars - only at the beginning of this year a Korean manufactured from US licenced military Jeep has been imported to Japan.

The Korean car manufacturers are not on the leading edge of production technology. The president of Hyundai corporation, Chung Se Yung, admits that their car manufacturing technology is "not at the level of Honda". But an executive of the car factories, H.B. Suh adds, that "from the US automobile industry the Hyundai has, however, nothing to learn any more" (HS 19.7.1987).

c) Electronics

The Korean 'electronics revolution' has been quite showing, too. The Koreans have plunged into the semiconducter business with American help, because Japanese firms refused to cooperate. There are many good examples of technological development. Textile company Kolon Int.Corp. started making TVs and other consumer electronics and moved further in cooperation with Fanuc to a joint robotmaking company in 1983.

The government plan for up to 1986 foresees a fast rise of high tech industries. R&D investments rise fast and they would like to join the OECD. In Daeduck Science town there are 11 research institutes set up and 3600 researches working there. KAIST, the "Korea Advanced Institute for Science and Technology", has 1500 researchers. KAIST is carrying out R&D projects for example in the fields of electronics and industrial automation.

Efforts to develop technology are mainly carried out by local capital. Japanese companies feel threatened by Korean competition, and foreign investors have become more cautious after labour discontent in the early 1980's and many foreign companies have left the country ever since (Junne 1986).

d) Industrial automation

According to tables 3. and 4., Korea seems to show a very much higher penetration of NCMts, CAD and robots than the other NICs. It is not either behind the OECD countries, except in robots.

Table 3. Approximate stock of electronically controlled capital goods in some countries, 1981-1983 (units) (Edqvist & Jacobsson (1985))

Country	Technology		
	CAD	NCMTs	Robots
Argentina	10	350	..
Brazil	15	834	50
Fed. Rep. of Germany	375	42500	4800
India	25	378	20
Rep. of Korea	63	1344	35
Sweden	208	5100	1850
United Kingdom	620	25000	1753
USA	6600	102000	8000

Table 4. An indicator of the intensity of use of electronically controlled capital goods - the number of respective technologies divided by the value added in the machinery and transport equipment sector in 1980 (in 1975 prices) - in some countries (ibid.)

Country	Technology		
	CAD	NCMTs	Robots
Argentina	3	103	..
Brazil	1	67	4
Fed. Rep. of Germany	6	658	74
India	8	118	6
Rep. of Korea	38	804	21
Sweden	33	809	293
United Kingdom	32	1302	91
USA	47	729	57

The relative use of CAD is very high in Korea. The usage of CAD is mainly seen as a means of catching up with the industrialized countries.

Table 5. Areas of application of CAD in the Republic of Korea in August 1984 (ibid.)

Area	No. of systems	%	No. of companies	%
Shipbuilding	14	22	7	15
Mechanical	12	19	10	21
Electronic	11	17	10	21
Construction	4	6	3	6
Plant Engineering	15	24	10	21
Other (archit. educ.etc)	7	11	7	15
Total	63	99	47	99

In spite of the rather good educational system, there is a shortage of skilled personnel in Korea, in partucularly of experienced designers and draughtsmen. This has slowened especially the diffusion of robots. Application problems have often been quite severe and local engineering capability doesn't yet exit to solve common application problems. External help from suppliers is difficult or impossible to obtain, when dealing with imported apparatus. Robots are still mainly substitutes for unskilled or semiskilled labour, which is a further factor slowening the diffusion.

e) Production and use of FMS and other automation techniques

The use of FMS is still very limited. According to Edqvist & Jacobsson (ibid.) it is mainly machine tool firms such as Tong-il, Daewoo and KIA that have an interest in FMS.

Tongil has installed a large-scale FMS in its own plant and Daewoo is about to introduce one on its own machine tool plant.

In 1984 there was no domestic production capability for FMS and only one FMS operating in Korea according to US Department of Commerce (US 1985). The report evaluated, that production of FMS in Korea was in an embryonic stage and unlikely to grow dramatically in the 80s because of Korea's shortcomings in computer and other semiconductor related technology, particularly microprocessor technology as well as the limited market.

The FMS market is neither expected to expand very fast. However, at least the major manufacturers of cars, Hyundai Motors and Daewoo Motors are expected to have FMS installed at their plants in the 1980s to manufacture automobile parts. In Korea parts having an annual requirement exceeding 100 000 units, such as transmission and axle parts, are manufactured by the automobile manufacturers while other parts are manufactured by small and medium sized companies under subcontracts.

The Korean Machine tool industry

In 1982 there were 91 firms registered as metalcutting machine tool makers in Korea. Most of them were very small, and firms with more than 200 employees accounted for 57 % of the gross output in 1982. The sector employs about 15 000 workers (Jacbsson, ibid, US ibid.). The domestic production consists of more than 50 types of machine tools (parts included): NC and CNC lathes machining centers, automatic deburring and tapping machines, grinding machines, horizontal boring and milling machines, and precision electrical discharge machines.

Until mid-1970s the industry was fairly small and exports vere insignificant. In the second half of the 70s, the industry went through and explosive growth. Production rose from 5.2 million US$ in 1971 to 178.4 million in 1984, and only 17 % of the total value produced was exported in 1984. The fast growth of machine tools production was based on the rapidly growing domestic markets.

First NC machines were produced by Wachon machinery works Co in 1977. programs for NC devices and the relay circuits for control devices developed in cooperation with the Korean advanced Institute of Science and Technology (KAIST). Since that, the both production and demand for CNC have grown remarkably. Jacobson (ibid.) evaluates, that the demand would grow to about 490 in 1988. That would mean a doubling of the market in comparison to 1984. The potential home market in Korea will, however, remain rather limited in comparison to West European countries.

Table 6. Production, trade and size of the local market for CNC lathes in Korea, in 1981 - 1984 (units) (Jacobsson, ibid)

Year	Production	Exports	Imports	Consumption	Share of CNC in total lathe inv.(%)
1981	84	46	26	64	37.7
1982	222	138	18	102	21.2
1983	233	65	47	215	28.6
1984	268	127	107	248	41.4

In early 1985 there were five firms producing CNC lathes in Korea. They were, according to US Department of Commerce (US 1985) include Daewoo Heavy Industries Ltd., Tongil Co., Whachon Machinery Works Co., Kia Machine Tool Co., and Korea Heavy Industries Ltd. Jacobsson (1986) mentions also five manufacturers, three of which are included in his case material, names only with letters B, D and J. In the following presentation, it is assumed, that B is Daewoo and D Whachon.

All these five companies are producing NC machine tools incorporating into their own machine tools NC control devices usally from Japanese companies such as Fanuc and Toshiba, which are also manufacturing now in Korea under licence.

Table 7. Characteristics of three Korean CNC producers in Jacobsson case study (ibid.)

	Employment	CNC sales	CNC models	Design No.	engineers % of total	Year of information
B	700	154	4	60	9 %	(1984)
D	800	68	2	30	4 %	(1984)
J	1500-1800	13	..	..	..	(1985)

1) Daewoo Heavy Industries Ltd.,

Daewoo has been producing NC lathes since 1980 and machining centers since 1983 under a licence from Toshiba. The production of machining centers in the first seven months of 1985 was 35 units, which makes it the largest produces in Korea. The firm also has a licence for another type of machining center from a German firm.

The firm has invested heavily on both equipment and skills. Altogether US$ 44 million have been invested in production facilities, which include 15 machining centers and 20 CNC lathes. The firm had an experimental FMC at installed in 1983 consisting of CNC lathes, a robot system, an automatic testing/measurement device, an automatic pallet feeder, an unmanned carrier, and a central control panel. Further, it was planning to install a fully fledged FMS consisting of seven machining centers with a central control unit and an automatic transport systems.

According to Jacobsson, the firm has invested in creating design skills in a way that no other NIC-based firm has been found to do. The R&D efforts have been notable. In 1983 the firm spent 5 % of its sales on R&D. It initiated already in 1978 design development efforts on CNC lathes. The first low performance products were not very succesful copies of Japanese machines. In 1984, it had the development work on a series of four CNC lathes completed, this time of own conception and of medium performance.

In 1985 Daewoo was developing NC controllers with self-diagnosis and automatic test/measurement functions. Plans of Daewoo in include supplying CNC lathes with robots and other FMS featuyres - altogether, at least the rudiments of an FMS industry in Korea.

2) Tongil Co.,

Tongil - machine tool and automobile parts manufacturer - was the developer of Korea's first machining center in 1981 and makes now machine tools with NC controllers imported from Fanuc, and has succeeded in developing a programmable controller, an integral part of NC controllers, on their own.

Tongil also has at the Kyungnam factories a FMS installed at the end 1984 with estimated costs of $3.8 million. The system is used to produce 30 different machine tool and automotive parts, 4500 parts per annum.

3) Whachon Machinery Works Co.

Whachon has a 25- year experience in machine tool production and it is the biggest producer of engine lathes in Korea. It is mainly producing for domestic markets; the export ratio is only abou 20 %. The firm designed the first Korean CNC lathe with the help from the Korean advanced Institute of Science and Technology (KAIST) in 1977. Nowadays it has two own CNC lathe designs (small units of low-medium performance) and one machining centre. It has also a CNC copy milling machine of own design.

The export customers for Whachons CNC lathes - e.g. 20 units exported in 1982 - are mainly small and medium sized firms using stand alone machines. In this regard the situation is quite alike with the other NIC based CNC lathe producers. But in the local market its main customer is Hyundai Automobile, where Whachons' lathes are put in a totally different context. The firm has also developed a aspecial material handling unit for Hyundai for simple cases of unmanned production.

4) Kia Machine Tool Co., and

5) Korea Heavy Industries Ltd.

Jacobsson mentions also a third firm "J", which might be Kia. It is a reasonably big company (1500 - 1800 employees) producing mainly machining centres and engine lathes. It introduced in 1981 a CNC lathe and produced 13 units in the first seven months of 1985. The firm, which has installed a fully fledged FMS in its plant, seems to be fairly strong in its technological capabilities. It has recently acquired two German firms that produce large custom-made machining centres and lathes. Heyligenstadt, the German CNC lathe producer, is often judged to ge the foremost problem solver in this industry in the FRG (ibid.). Thus, Korea has acquired this firm's capabilities through financial takeover.

In mid-1980 the Korean Government provided funds to promote the purchase of domestically-produced machines. The government program was designed to spur investment in plant and equipment on the part of the machinergy industry. The government initially allocated $88.9 million for national ivnestment funds, $49.3 million for small and medium sized firms, and $65,8 million went to industrial banks for their machinery funds. Another $164.6 million was later added to the program. In 1981 the government provided a number of incentives to spur investment in machinery including tax credits, R&D assistance, grants and low cost financing. The Korean governments targets for the metalworking machine tool industry in 1986 included production value added at $950 million and exports - including metal forming machinery - totalling $ 550 million, or 57.9 % of production. 60 % of the machine tools in use by Korea are domestically produced.

Explaning the development

a) Comparative advantage and governmental policies

In the first phase of accelerated export production in the 60s the theory of comparative advantage appeared a plausible explanation of the process. Up to the present it might also be applicable to a major part of Koreas exports: textiles, garments, partly eletronics. But the most spectacular successes shipbuilding, steel and manufacture of steel are mostly comparative advantages created by the governmental decisions and policies, not by free market forces.

In sum: while the backbone of export performance of Korea might be attributable to a genuine comparative advantage, the second generation of growth industries seemed more likely to be the products of government gamble. There were problems in both respects. Lower-cost producers affected the basic exports; under a decade, China expanded its garment exports so swiftly that it became the fourth largest exporter amond the LDCs. Koreans have estimated that the Chinese wages were 30 to 40 % below the Korean level. Also, the new industries directly affected old-established sectors of production in the industrialized countries, evoking protectionism in the richest markets.

b) Competing explanations

The main reasons usually given for Korean economic and technogical development can be grouped under four headlines (Harris 1986, c. Woronoff 1986): usually either low wages, governmental policy, US aid or investments of multinational corporations are seen as the main agents behing the success.

1) Low wages? Since low wages are general in developing countries, Korea's advantage is limited. Korean wages were not the lowest in the world at the beginning of fast growth and they have increased faster than in most developing countries - in real terms by over 7 % per year since the sixties. Though, for example in automobile manufacturing the wage level in Korea is are obviously a lot under the Japanese level, which has given them a real relative advantage in relation to Japan in conmpetition in the american markets for example in 1986 (HS 19.7.1987).

2) The interaction of government policy with social factors: a high propensity to work and save? The government created a 'free trade' regime for exports. This with incentives, labour policy, and exchange rate which much of the time reduced the price of exports and made imports relatively expensive. Korea has subsidized exports and redistributed income domestically in order to cheapen exports so to say 'artificially'. However, the timing does not completely fit for this explanation. The export expansion began in 1959 whereas the policy changes to export growth occurred later. Korea did not pursue simple exports promotion; to this day, it substitutes for imports as a tactic of forcing industrial growth.

3) US aid? Also US civil aid was very important in the financing of infrastructure and education. However, the accelerated growth came later and was partly the result of attempts to cope with the declining US aid. It may have been a necessary conditon of development, but not a sufficient one.

4) Investment by MNCs? In fact, Korea is not a notable recipient of foreign investment; Foreign investment as a ratio of GNP between 1972 and 1976 in Korea was 5.5, in Brazil 9.6, Colombia 10.6, Taiwan 6.2 and Turkey 10.5. The volume of foreign investment does not correlete with the scale of exports - in 1980, Brazil with the largest foreign investment had exports of $9.2 billion, Korea $19.2 billion. Furthermore, foreign investment followed accelerated growth rather than lead it. The largest foreign investors by nationality were Japanese

companies (with 61% of the total in 1978, 48 % in 1984) and their entry came after the normalization of Korean-Japanese relations in 1965. They were greatly small and medium sized companies for whom the one Korean plant was the sole overseas investment, and usually operated jointly with a Korean partner. The great MNCs were rather remote in such a context. In the seventies and eighties Korean companies seemed to be replacing some of he largest Japanese operations in the field of electronic goods. The foreigners actually came after growth began and were heavily concentrated in particular fields. The pioneers in the first half of the sixties were Koreans. In other sectors of key export production at different times - ships, footwear, iron and steel, metal manufactruing, non metallic minerals, rubber goods, precision instruments, wigs, plywood - there were no foreign companies.

It is quite obvious, that all explanations above played some role, none of them alone was the effective cause. We need to understand the interaction between a pecurial and temporary set of conditions in Korea and new phases in the external environment. Korea was not manipulated from outside, but did exploit changing opportunities. A more precise analysis of the changes in the external environment and the the Korean governmental policies, and the institutional settings of industry and national economy is needed to understand the factors underlying the Korean development and success - and to evaluate the possible future trends.