CHAPTER I

MANAGING TECHNOLOGICAL CHANGE IN DEVELOPING COUNTRIES:

THE IMPACT AND POLICY IMPLICATIONS OF MICROELECTRONICS

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March 1986

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ACKNOWLEDGEMENT

I wish to express my appreciation to the Commonwealth Secretariat for the opportunity to contribute to the deliberations of its Working Group on the Management of Technological Change. Thanks are also due to the members of that Group, especially Dr. Linda Lim, and to the staff of the Secretariat, in particular, Mr Ian Thomas and Dr. Vincent Cable for their valuable comments on earlier drafts. They, of course, bear no responsibility for the views expressed in this monograph as this rests entirely with the author.

INTRODUCTION

It is by now a common observation that microelectronics technology has the potential to transform the products we consume, the way in which they are produced and indeed the whole framework of social relations within society and between countries. This dramatic view receives strong support from developments that have already taken place primarily within the advanced industrial economies over the last five to eight years. In those sectors where the use of microelectronics is most advanced, the rate of change in product and process technology has been particularly striking. Numerous entirely new products and devices have been developed and marketed. A wide range of enterprises offering a variety of computer and microelectronics related services have seemingly blossomed overnight and grown at phenomenal rates. At the same time, the characteristics of many existing goods have been measurably enhanced and often completely transformed by the incorporation of the technology. The production process in a number of established industries has been fundamentally and dramatically altered, as have the composition and skill profiles required of the work force.

Given the well publicized nature of these changes, it is perhaps not surprising that the advent of microelectronics has provoked a deal of discussion and debate. Much of this has centered on the possible impacts that the widespread use of microelectronics would have on the functioning of society and the structure of the world economy. Many views have been put forward regarding the scale and character of these effects. For some, the assessment is one of enthusiastic optimism which sees the use of microelectronics bringing many benefits in the guise of new jobs, the elimination of dangerous and alienating occupations, and a greatly increased amount of leisure time. This argument is countered by those who offer a more pessimistic vision which foresees the spectre of mass unemployment and social crisis, particularly if new labour displacing systems are introduced without the consent or participation of the work force.

At the international level, there has been concern and speculation about the possible effects on competitive advantage and the international ranking of the developed countries. One prevalent line of argument has been that the failure or inability of a country to adopt microelectronics-related innovations (MRIs) could result in the loss of international and domestic market shares to foreign competitors who have successfully exploited the potential of the new technology. Opponents of this perception contend that the international rate of diffusion of the technology in many sectors will be slower than forecast even among the most advanced industrial economies. The longer lead times foreseen would therefore allow a competitive response to develop. This in turn would facilitate structural adjustments even in the weaker economies which would absorb the displaced labour without significant disruption to society.

These debates over the future developments in the advanced industrial countries are still unresolved. However, broad trends can already be identified and most governments have introduced a wide range of policies to encourage further development and diffusion of microelectronics and information technologies. Nevertheless, much uncertainty about long term trend effects remains; the one thing that does appear certain is that information technologies will be a central feature of the future in the industrialized world - whether these futures be bleak or bountiful.

Much less is known and understood about the implications of microelectronics for the countries of the Third World. Some, particularly the newly industrializing countries (NICs) in Asia, have benefited enormously from the rapid growth in the role of electronics in the world economy. For many other countries however the opportunities and challenges posed by information technology are only beginning to manifest themselves. Once again there has been a good deal of speculation. Some see in microelectronics and its application the opportunity for the Third World to take a technological "leapfrog" over the long standing problems which have so far constrained their development efforts.

Other observers are more apprehensive. They see the technological gap between the First and Third World irrevocably widening. Central among these concerns is that automation in the North will undercut the Third World's ability to compete in international markets. More fundamentally, an open embrace of information technology by the Third World in the absence of sensible policies to ensure the appropriate level of its introduction and to mitigate any negative impacts that would arise is seen by a number of analysts as likely to have little or no beneficial effect on the development process.

Both points of view are still highly speculative. The small body of empirical studies which address Third World issues almost reassuringly contradict these hypotheses as often as they confirm them. In this situation the need for caution is clear. But given the pervasive potential of microelectronics, the rapid pace of developments and the deep integration of many countries into the world economy, there is little question that the technology will both directly and indirectly affect the Third World. Consequently, the developing countries and the development community at large need to address the wide range of issues raised by microelectronics as comprehensively as possible.

This monograph was commissioned by the Commonwealth Secretariat as an input to its Working Group on the Management of Technological Change. The first part sets out to describe and delineate the areas of application of microelectronics. Under this heading we have included developments in both the electronics sector and in the industrial and service sectors. These areas are covered separately in Chapters 1 and 2. In Chapter 3 we move on to consider the national and international impacts of the technology. The material in this chapter has been organized to bring out the implications most directly relevant to developing countries. In Chapter 4 the nature and orientation of existing policy mechanisms are reviewed. In the case of the developed countries and some of the more advanced developing countries, policies relating to microelectronics are well developed. For most of the Third World countries however, technology policies in general are not well articulated and the specific challenges of the new technologies are rarely addressed. In Chapter 5 we put forward some broad suggestions regarding the policy options open to economies at different stages of development. Once again we will distinguish between policies relating to the electronics sector and those concerned more broadly with the industrial sector.

There are a number of specific features of the monograph which should be noted here. First, we have generally oriented our discussions towards developments and implications of relevance to the developing countries. Second, in doing this we have however relied heavily on material drawn from the experience of the developed economies. In part this is necessary because most of the available information deals with these countries. However, it is also the case that developments related to microelectronics are furthest advanced in the developed economies. Developing countries will, therefore, be most directly affected by the character of the changes taking place there and by the rate at which these changes occur.

Finally, the particular characteristics of microelectronics technology mean that its effects are extremely pervasive not only in terms of the range of sectors, products and processes being affected but also because these are occurring on multiple levels. It is simply not possible in a short report to deal comprehensively with all of the dimensions. Therefore, we have been deliberately selective rather than comprehensive, while trying to concentrate on what we believe are the most important policy issues confronting developing countries.

CHAPTER 1

MICROELECTRONICS AND THE ELECTRONICS COMPLEX: KEYS TO THE TECHNOLOGICAL REVOLUTION AND MAIN CARRIERS IN THE THIRD WORLD

In this chapter our central concern is with the key technical and economic characteristics of microelectronics technology and with the application of the technology within the electronics complex.(1) We believe the electronics complex and its products will be the most important "carrier" of the impact of microelectronics on the Third World in the short to medium term; there are many reasons for this. It is in the electronics complex where the greatest opportunities have opened up for developing countries to enter into new markets. The diffusion of electronics products, particularly consumer electronics, is already affecting consumption patterns in even the poorest countries. One particular product, the microcomputer, offers enormous scope for immediate applications which could yield substantial social benefits. It is also in the electronics complex where technical change in the North is already affecting the low wage based competitive advantage of a large number of developing country exporters.

Finally, the pervasive character of microelectronics means that the electronics sector will increasingly come to play a role in economic development akin to that attributed to the capital goods industry. Like capital goods, the products of the sector will be a driving force for technical change in user industries and hence for capital accumulation in the economy. More importantly, electronics related skills will have wide applicability throughout the economy, both in relation to facilitating the appropriate choice of (increasingly electronics intensive) technologies and towards allowing the economy first to adapt imported techniques to local conditions, and eventually to develop indigenous technologies.

In section 1, we describe briefly the historical evolution of the electronics industry and the most important features of the "microelectronics revolution" which give the technology such a wide scope of application. In sections 3 - 6 we try to capture the most important trends resulting from the applications of microelectronics in the electronics complex by focussing in detail on developments in consumer electronics, in computers and in software.

Section 2: Evolution of Microelectronics and its Role as a Heartland Technology

The historical antecedents of microelectronics technology and the electronics industry date back to the discovery of electricity at the end of the 19th century. Continually since then, the electrical industry has remained one of the principal sources of technological innovation in the advanced industrial economies. Soete and Dosi (1983) show how technical change in power generating equipment and electrical components led to the emergence of a "cluster" of new industries involved in the development and production of capital equipment, transmission and control systems, and a wide range of new electricity-based consumer durables such as lamps, radios, refrigerators etc. The high rate of innovation associated with the emergence of this "cluster" of new industries was accompanied by rapid growth in demand due to the substitution of electricity for steam power, rising electricity requirements per unit of output as production mechanization increased, the development of an electricity grid and a change in the composition of the "consumption basket" towards electricity based commodities.

The extensive interaction of technical change and demand stimulated far reaching structural changes in the industrial sector, substantial improvements in factor productivity and associated rises in real wages and rates of profit, and a fundamental alteration of social relations of production.(2) The generally upwards trend in economic growth (i.e. in demand, investment, output, trade and consumption) which characterized the period between 1900 and 1930 rested in a large part on the stimulus provided by the electrical industry and demand for its products - although similar processes were at work in other sectors such as chemicals. In the period since World War II, the structure and output of the electrical industry was itself transformed by the development of electronics technology and the semi-conductor based transistor. Freeman et al (1982) show how (in a process similar to that described above) rapid technical change in semi-conductor technology stimulated successive rounds of product and process innovation in user industries which in turn partly underlay the virtuous cycle of growth and expansion in countries in the OECD during the 1950s, 1960s and early 1970s.

Understanding the complex way in which technical change interacts with economic and social variables is crucial to our assessment of future trends related to microelectronics and we shall return to the topic in Chapter 3. Here we wish primarily to draw attention to the central features of the process of technical change sparked off by the development of semi-conductor technology and the electronic processing of information. The first point to note is that the evolution of the electronics industry since 1951 (when Bell Labs first developed the point contact transistor) has been marked by an exceedingly rapid rate of product and process innovation. This is shown in Table 1.1 which details some of the major semi-conductor product and process innovations developed between 1951 and 1978.

TABLE 1.1

Key Innovations in the Semiconductor Industry

A Product Innovations

Innovation	Firm	First Production
Point contact transistor	Western Electric	1951
Integrated circuit	Texas Instruments/Fairchild	1960-61
Light-emitting diode	Texas Instruments	1964
MOS integrated circuit	General Microelectronics/ General Instruments	1965
Magnetic bubble memory	Western Electric	(1968-77)
CMOS IC	RCA	1968
Schottky TTL	Texas Instruments	1969-70
1-K MOS RAM	Intel/AMS	1969
Microprocessor	Intel	1971-72
Uncommitted logic arrays	Ferranti	1973-74
1 transistor cell dynamic RAM (1 K bits)	Intel/Mostek/TI	1974
16-K MOS RAM	Intel/Mostek	1976
Micro computer (8048)	Intel	1977
64-K RAM	Fujitsu	1978

B Process Innovations

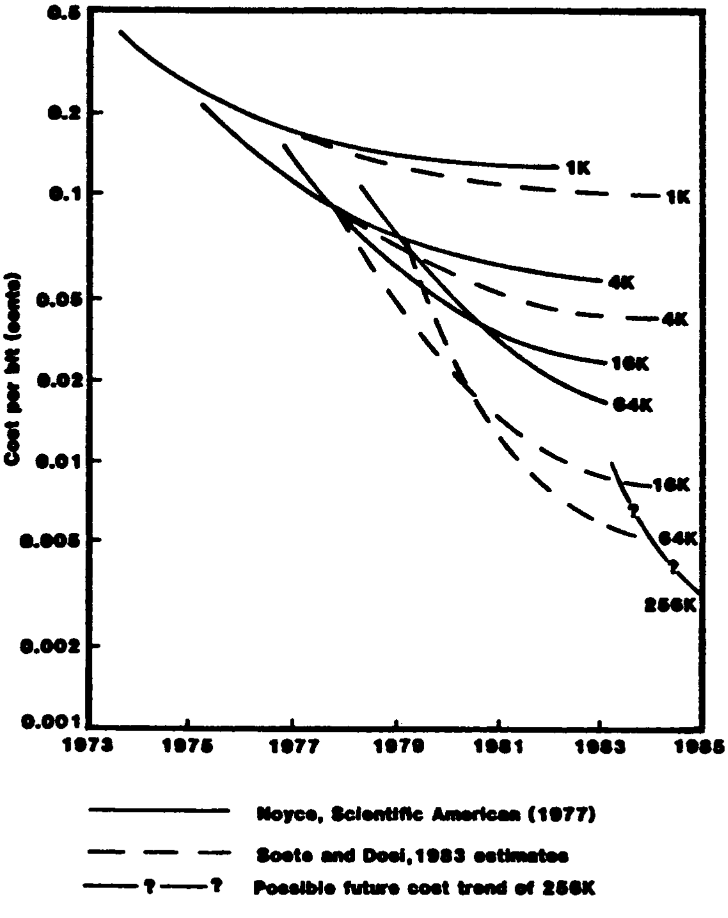
Innovation	Firm	Date of Introduction
Single crystal growing	Western Electric	1950
Oxide masking and diffusion	Western Electric	1950
Planar process	Fairchild	1960
Beam lead	Western Electric	1964
Ion implantation	Mostek	1970
Schottky junction	TI	1970
Integrated injection logic	Philips	1973
Plasma etching	Standard Telecom Labs (UK)	1974
Deep ultra-violet photolithography	Perkin-Elmer	1977

Source: adapted from Soete and Dosi (1983)

Though more recent innovations have not been included (because of the time lag necessary to judge their importance), there is little doubt that the pace of change will remain high for many years to come. (3)

The development of the microprocessor by Intel in 1971, though following the trends of component miniaturization and reduced unit costs established earlier, represented a major technical and economic advance over the transistors and integrated circuits of the 1950s and 1960s. For the first time it was possible to incorporate all of the elements of a computer on a single chip. Since 1971, the dominant technical trend in microelectronics has been the rapid, continuous reduction in circuit size and a corresponding increase in chip density.(4) The most important economic implication of this trend has been a dramatic decline in the unit costs of performance as measured by the amount of information that can be processed or stored on a chip. This crucial trend is demonstrated in Figure 1.1 which shows the decline in units costs for random access memories (RAMs) between 1971 and 1985. As the figure shows, the annual 35 per cent reduction in unit costs that has actually been achieved far exceeded the original estimates made by Noyce in his well known 1977 article in Scientific American.

Figure 1.1: Trends in Semiconductor Memory Cost per bit



Source: Soete and Dosi, 1983

Declining unit prices have led to continually rising demand for semi-conductor devices as the scope for applications grows ever greater in both the electronics complex and the industrial sector. This is demonstrated by Table 1.2 which shows that the world market for semi-conductors has been growing faster than that for electronics as a whole. This trend is expected to continue well into the future.

TABLE 1.2

Value Share of Semiconductor sales in Electronic Equipment, 1970-1990 (US$ billions)

Year	World electronics market	World semiconductor consumption	Semiconductor share of value (per cent)
1970	50	2.2	5.8
1980	200	14.0	7.5
1985	380	35.0	9.0
1990	750	80.0	11.0

Source: adapted from O'Connor (1985)

The trends in unit costs and sales volume are indeed impressive. Yet they fail to capture three other key technical characteristics of microelectronics. First, due to its reliance on digital logic, microelectronics is essentially an information processsing technology. The information processing function is critical in all production processes, in all service activities and in many products. Microelectronics devices are therefore applicable in any situation where information processing is required - and most importantly the common use of digital devices will create a universal language for information processing and transmission.

Second the devices are programmable and therefore a single chip design can be adapted to a myriad array of different applications. This allows for important scale economies to be gained by producers. From the users point of view this feature means that programmes can be set which respond to in-situ changes in operating parameters and allow the system to follow an optimal path under varying conditions.

Thirdly and most importantly, are the implications of increasing chip density. This means that there has been a continuous rise in the amount of information that can be handled by the devices and a simultaneous reduction in the time required to do this by several orders of magnitude. As a result simply in terms of straight-forward quantitative improvements in cost-effectiveness, microelectronic devices will be economically superior to other information processing systems. In addition this characteristic facilitates the increasing convergence of previously separate activities and previous separate industries producing these products. It also allows the "real-time" handling of complex information sets and has proved crucial in the development of highly sophisticated process control systems and automation technologies such as computer-aided-design systems.

The collective importance of these technical features for user industries and for the economy as a whole is dramatic and indeed "revolutionary" in the fullest sense of the word. Microelectronics technology is imbued with a set of capabilities which simply did not exist in previous vintages of electronics. As a result, vast possibilities are opened up for the development of entirely new products, processes, services and even industries. Secondly, the considerable improvements in unit costs and in performance documented above constitute an extremely powerful set of economic incentives which virtually compel the substitution of microelectronics based systems for earlier vintages of information processing technology in existing systems and products. As we shall see below, both of these effects have had a very significant impact on the electronics complex itself, which as yet is the main user of the technology. More importantly, however, both the new product effect and the substitution effect extend well beyond electronics industries to include virtually every segment of the industrial and service sectors, as well as the agricultural industry.

It is this process of rapid change in the core technology itself (i.e. microelectronics) combined with the spread of the technology throughout the economy which is the phenomena at the heart of the "microelectronics revolution" (Soete and Dosi, 1983). It confers upon the technology a generic and pervasive character which gives it wide applicability across sectors. The economic gains associated with the use of the technology and the multitude of new product opportunities generates rising demand and new profitable investment opportunities. These in turn can lead to increased demands for capital equipment, services and employment needs. Finally, the diffusion of the technology creates a set of technological imbalances within the economy which themselves stimulate further rounds of technical change, investment and employment creation. Microelectronics therefore possesses all the characteristics of what Freeman (1979) calls "heartland" technologies, and, like the earlier similar heartland technologies of steampower, electricity and the internal combustion engine, it possesses the ability to revolutionize not only the economy but the very nature of society.

Trends and applications in the electronics complex

In the next three sections we try to give a broad overview of the most important developments that the advent of microelectronics has caused within the electronics complex. In so doing we have chosen to do more than just tick off the enormous variety of areas where the technology has been applied. These developments are important of course but they depict only one part of the story. We believe a broader view is necessary since the formulation of policy in this field must take into account not only applications (and market opportunities) but also trends in technical change, the structure of the sector and the nature of competition, the strategies of the leading actors, and the barriers to entry which are developing.

Before begining our more detailed analysis we want to make a few broad contextual comments. The first is to simply point out that the electronics complex is well on the way to becoming the single most important sector in the world economy. The sheer size of the sector can be seen from Table 1.3 and by the fact that by 1984 (if not earlier) the collective output of the electronics sector was already equivalent to that of the world's steel industry. Despite the continued presence of recessionary pressures in the world economy the industry is expected to continue to expand at or above historical trends, with specific segments growing much quicker.

Second, one of the most important features of the expansion of the electronics industry has been the prominent role played by the Third World as exporters of electronics products. Initially brought into the international division of labour in the industry as a result of the efforts of transnational corporations (TNCs) to reduce labour costs, national firms have begun to figure prominently, particularly in sectors such as consumer electronics where they have established an internationally competitive mass production capability. This is shown by Table 1.4, where the annual growth rate of Third World exports in seven categories of electronics products exceeded that of world exports by more than two and sometimes

TABLE 1.3

World Electronics Production (US$ billions)

1965	1970	1975	1977	1981	1985	1991
Actual				Estimate		
38	58	84	108	150-368*	230-560*	845*

Sources: World Bank (1980)
* Mackintosh (1980)

TABLE 1.4

Third World Exports of Electronics Products, 1967-1980

SITC Class (revised)	1967		1973		1978		1980		% annual growth rate 1970-1980
	Value ($000)	% of world	Value ($000)	% of world	Value ($000)	% of world	Value ($000)	% of world	
729 - Electrical machinery, n.e.s.	72,101	2.25	760,774	6.94	2,918,509	10.34	4,930,872	12.68	34.2
724 - Telecommunications equipment	64,954	2.36	631,082	6.78	2,661,124	11.47	5,444,515	17.83	33.5
714 - Office machines	30,011	1.31	330,299	4.38	720,959	4.23	1,238,343	4.26	28.7
722 - Electrical power, switchgear	20,769	0.88	145,100	2.10	683,734	3.60	1,536,330	6.02	37.7
891 - Sound recorders, producers	8,811	0.93	111,661	3.60	543,938	7.85	960,083	8.76	42.8
861 - Instruments, apparatus	16,487	0.75	183,268	2.99	482,059	3.29	850,341	4.10	35.4
726 - Electromedical, x-ray	395	0.20	4,820	0.73	6,525	0.31	12,887	0.43	33.3
Total Electronic	213,528		2,167,004		8,016,848		14,973,371		

Source: adapted from O'Connor (1983)

three times. The gains in SITC 729 (electrical machinery electronic components) and SITC 724 (telecommunications equipment) are particularly notable because of the size of market share and the greater technological complexities of some of these products compared to the other categories.

Third, as is well known, a few developing countries have accounted for the great majority of Third World electronics exports. Most important have been the NICs in Asia, particularly Hong Kong, Singapore and South Korea, which are exceptionally strong in virtually every product category. Five other countries form the "second tier" of Third World electronics exporters - Taiwan, Malaysia and the Philippines in Asia, and Mexico and Brazil in Latin America. The high degree of concentration of export share enjoyed by these countries is reflected in Table 1.5 which shows the four developing country leading exporters of telecommunications and electronics components to the US between 1967 and 1980.

TABLE 1.5

Share of Developing World Export of Telecommunication Equipment and Electrical Machinery from Selected Developing Countries, 1967-1980

Telecommunications		Electrical Machinery	
	% of developing world		% of developing world
1967		1967	
Hong Kong	75.80	Hong Kong	66.30
Singapore	5.54	Singapore	11.70
Mexico	5.35	Brazil	4.68
Korea	3.61	Korea	4.32
	90.30		87.00
1973		1973	
Hong Kong	42.85	Singapore	31.51
Singapore	16.02	Hong Kong	28.33
Mexico	13.30	Korea	26.88
Korea	12.63	Brazil	3.02
	84.80		89.74
1978		1978	
Korea	22.98	Singapore	31.53
Hong Kong	20.74	Malaysia	19.03
Singapore	17.59	Korea	16.67
Brazil	4.94	Hong Kong	9.06
	66.25		76.29
1980		1980	
Singapore	23.13	Singapore	28.97
Korea	17.31	Malaysia	22.05
Hong Kong	16.86	Korea	14.13
Brazil	2.74	Hong Kong	8.24
	60.04	73.39	

Source: adapted from O'Connor (1983)

Despite the strength of this small group of exporters a number of other developing countries have also managed to achieve a considerable rate of growth of exports in specific product categories, even though they still account for a small share of total exports. Table 1.6 reflects this trend.

TABLE 1.6

Exports of Electronics from Selected Developing Countries, 1967-1979 (US$,000)

Total Electronics	1967	1973	1979	Average growth rate (1967-1979)	Average growth rate (1967-1973)	Average growth rate (1973-1979)
1 Singapore	7125	217974	2136595	60.85	76.85	46.29
2 Korea	5419	325612	1581234	60.48	97.91	30.13
3 Hong Kong	73658	392387	1205769	26.23	32.15	20.58
4 Malaysia	192	9357	963760	103.42	91.12	116.51
5 Brazil	11594	86048	306328	31.37	39.66	23.57
6 Thailand	9	775	148627	124.64	110.14	140.14
7 Argentina	13553	42577	72173	14.96	21.02	9.19
8 Philippines	0	568	27831	-	-	91.29
9 Kuwait	0	8316	62880	-	-	40.10
10 Indonesia	0	0	82492	-	-	-
11 India	2004	14812	28425	24.73	39.57	11.48
12 Mexico	5269	154153	27317	14.70	75.54	-25.05
13 Barbados	1	1094	5340	104.47	221.00	30.24

Source: adapted from O'Connor (1983)

There are of course many other features of the structure and orientation of the electronics industry which are important from a broad policy perspective. One is the obvious fact that TNCs play a major role in a number of sectors as components and consumer electronics and their strategies and actions need to be taken account of. Another factor is that some of the products where the Third World has become a successful exporter are low technology products whose manufacture entails only limited local linkages. Employment in some cases is not growing nearly as fast as exports in spite of the emphasis this is given by many countries, though it is important to note that electronics sector employment has frequently grown much more quickly than employment in other sectors in the past. Finally, international competitiveness is increasingly determined by factors other than low wages, thus posing considerable barriers for entry to new entrants. We try to illustrate these points and others in the sections that follow.

Section 3: Consumer Electronics

Developments in the consumer electronics sector provide some very good examples of trends which are common throughout the electronics complex. The first trend has been the tremendous proliferation of new products based on microelectronics. This is demonstrated in Figure 1.2. Burgeoning demand for these new products has stimulated the renovation and resurgence of what had been a mature industry. For instance, in the US sales for all consumer electronics products were $16.1 billion in 1982, $20.1 billion in 1983 and an estimated $22.7 billion in 1984 - a 41 per cent increase over three years. Although the European market is not really as buoyant overall as the US, certain segments are growing rapidly, such as video tape recorders (VTRs) where unit sales will grow from 5.6 million in 1983 to 6.6 million in 1985 (Electronics Week 1984).

The second feature to note is that the unit cost, content and function of many consumer electronics products have changed dramatically due to technical changes in microelectronics. In the case of electronic calculators, unit prices have decreased from $170.00 in 1965 for a business calculator relying on discrete components, to less than $5.00 in 1980 for calculators using large-scale integrated (LSI) circuits.

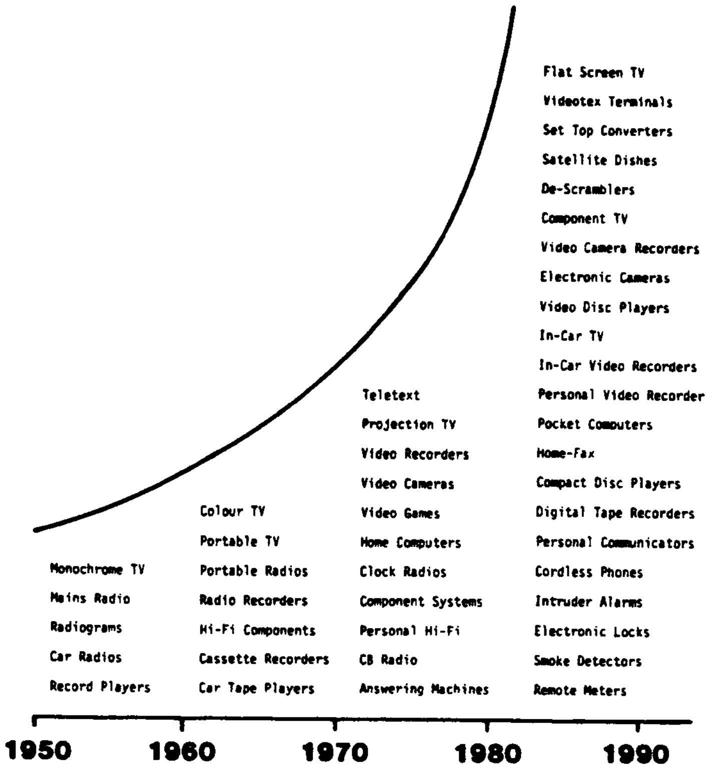
This has occurred at the same time that the range of functions has increased enormously (Rada, 1983). This same trend has also emerged in the case of colour TV sets. Mackintosh (1984) shows how as the consumer price index rose by 125 per cent over the 1975-1982 period, the price index for colour TVs actually dropped by 10 per cent. The number of components has also been reduced dramatically. For the new generation of digital colour TVs, five very large-scale integraters (VSLI) and three peripheral chips have replaced 25 integrated circuits, 20 transistors and 350 other conventional components. The TV is also in the process of being transformed from a passive entertainment device into a multipurpose component of an interactive information system. Not only will the new generation of colour TVs receive transmissions in different standards (i.e. PAL or SECAM) without a decoder, they will have the capacity to be linked into a wide variety of compatible devices, as shown by Figure 1.3.

This transformation of the colour TV from a discrete product to a component of an integrated system is paralleled by similar developments elsewhere. Take the case of the electronic cash register. The substitution of electronic components for electromechanical components converts cash registers from mere adding machines to interactive data entry terminals capable of providing an extremely wide range of services via a network of interconnected information systems - the detailed monitoring of transaction patterns for in-house store management for inventory control (via computer based connections backwards to the goods distribution network) and electronic funds transfer (with connections forward to the financial network).

These developments illustrate one of the key phenomena of the microelectronics revolution - the trend towards convergence. Convergence is occurring on multiple levels, each with different implications. First, component integration within the product means a shift in value added away from final product manufacture to the components themselves and by extension to component producers. Second, the product is now part of a system. Product suppliers therefore are led to integrate backwards into component supply and forward into becoming suppliers of total systems compatible with other systems. As a result, major new technological and size related barriers for entry are emerging. Third, for the systems to be able to communicate with each other, the appropriate communications network must be in place to facilitate the exchange at transmission of digital (and satellite) based information. This feature emphasizes the crucial role of the telecommunications system as the "highways" of the information age. As we shall see, these same trends toward convergence are taking place in relation to computers (discussed in the next section), in office automation and of course via the advance in industrial automation discussed in the next chapter.

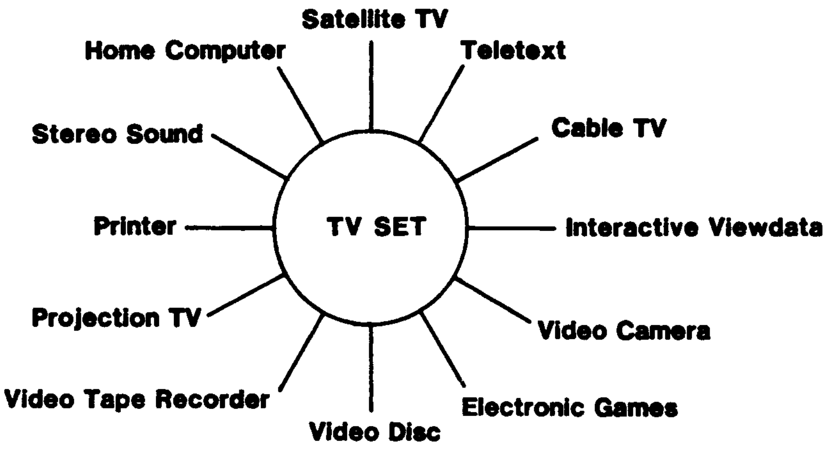
The evolution of consumer electronics products from maturity to dematurity due to microelectronics also illuminates the changing fortunes of developing countries in the electronics industry. Until recently, the assembly of consumer electronics products was highly labour intensive and for many developing countries offered a relatively easy entry point into the international electronics market. This is what happened in the Asian countries in the 1960s and 1970s when exports of products such as radios, tape recorders, watches, calculators and black and white (and later colour) TVs expanded at more than 20 per cent annually. A good example of this phenomenal expansion comes from the Hong Kong watch industry. In 1970, Hong Kong had 176 watch companies employing 7,000 people. By 1979 this had grown to 770 companies employing 32,000 people. Exports increased from 28.5 million units in 1970 to 119 million in 1980 (Williams, 1982). One sign of the success of Asian consumer electronics exporters can be seen in the rapid rise of UK imports of consumer electronics between 1975 and 1980. These grew from £179 million to £489 million with more than 60 per cent being imported from Asian developing countries (Soete and Dosi, 1983).

Figure 1.2: The Expanding Consumer Electronics Universe



Source: MacKintosh, 1984

Figure 1.3: Television as Part of the Communication System



Source: Pannenborg, AE, "Competition in TV markets, the case of Phillips", IMI, Geneva March 1983 p27

TNC involvement in local assembly for export was a crucial element in the initial expansion of the consumer electronics industry in Asia. However, by restricting foreign competition in the domestic market, a number of countries have been able to develop a strong local industry in certain "mature" products where design has standardized and process change is only incremental in nature. Independent producers are strongest in South Korea and the other NICs where they exhibit both a good design capability and have high local content in their component supply. Even Thailand, where most components are imported, boasts a domestic industry composed of seven large radio and TV assemblers, 20 small-scale factories and a large cottage industry carrying out repairs and assembling copies of popular products - the latter capability extends all the way through to the design and assembly of copies of personal computers (Clark and Cable, 1982).

The emergence of Asian countries as the dominant world source of consumer electronics products, based on the advantages of their low wages, location and attractive governmental incentives, was the principal feature of the industry during the 1960s and 1970s, and has of course persuaded many other countries to attempt to follow the same path. Indeed even today in certain product categories, new entrant developing countries may well be able to retrace these steps, and by concentrating first on satisfying the domestic market they can probably do this either with or without TNC involvement. However, where the intended objective is the export market in more sophisticated products, a whole new set of difficulties has arisen which suggests some form of mutually beneficial co-operation with TNCs will be necessary.

Again, the situation of the Asian countries is instructive in this regard. Despite a growing local industry, most Asian consumer electronics producers are heavily dependent on Japanese TNCs either for product design know-how or for components. On average these countries import more than 70 per cent of their ICs, precision component parts and colour TV components from Japan (Clark and Cable, 1982). Such dependence is proving problematic as the Asian companies try to upgrade their product capabilities to handle the new generation of advanced products such as VTRs, video disc systems, sophisticated audio products and new vintages of colour TVs incorporating view data and telex facilities. As noted above, these products incorporate significant technical advances in product and process technology based in large part upon the advances in components technology described in Section 2.

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. From the point of view of the future competitive position of these countries, this posture can cause problems. For instance, Rada (1983) cites statements by the Chairman of the Electronics Industry Association of Korea who argued that the speed of technological development, the lack of technology transfer from the Japanese and the severe competition in the international market were making it exceedingly difficult and costly to obtain a large market share in high technology products. The strength of the Japanese in new consumer electronics products is highlighted by their success in VTRs. In the mid 1970s Japanese VTR producers introduced a number of product and process improvements to existing VTR technology. Product redesign was carried out to reduce component numbers and allowed the use of automatic insertion equipment to achieve scale economies and lower unit costs.(5) At the same time quality was greatly improved via the addition of a variety of operational features. As Table 1.7 shows, Japanese VTR producers in five years exploited these gains and their protected domestic market to increase production from 350,000 units to more than eight million, in the process, they thereby captured 95% of the world market.

TABLE 1.7

Japan's Production and Export of Video-Tape Recorders, 1976-1982
(Units)

	Export	Production	Export/Production
1976	150,000	350,000	0.43
1977	400,000	800,000	0.50
1978	950,000	1,400,000	0.68
1979	1,600,000	2,200,000	0.73
1980	3,400,000	4,400,000	0.77
1981	6,900,000	8,400,000	0.82
1982		14,000,000	

Source: adapted from Sigurdson (1983)

What is particularly significant about this situation is that, as with earlier consumer electronics products, Japanese dominance in VTRs is now being diluted - but whereas before, this dilution would have been led by the NICs' rapid assimilation of the technology from Japan, it is now occurring via Japanese manufacturing investments overseas in the US and Europe and through cross-licensing agreements with OECD firms. The following quote emphasizes this point:

> "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." (Clark and Cable, 1982, p.33).

The above moves on the part of Japanese (and increasingly South Korean) firms towards inward investment in the U.S. have been driven by their fears that future protectionist barriers will severely restrain inport levels. An important facilitating factor allowing these new investments to remain competitive with imports from low wage countries lies in the high degree of production automation and more sophisticated product technology.

European firms are now pursuing the same strategy. The renewed strength of the UK colour TV industry is due in part to that industry's rapid pursuit of the "example set by Japan with automation of production, continued innovation in design and improvements in quality, cost and availability of components" (NEDO, 1981, p.25). Due to a heavy investment programme that has been continuing since 1979 the industry is expected to be competitive with OECD and Asian competitors, including Japan, by 1985.(6) Philips, the Dutch electronics multinational has also recently claimed that due to automation "productivity grew by 12 per cent last year in its six television tube plants which are now operating at, or close to, Japanese levels of efficiency." (Financial Times, October 26, 1983). The above discussion has a number of implications for future strategies of the consumer electronics industry in Asia and other regions which are discussed in Chapter 5.

Section 4: Computers

The evolution of computers and of the computer industry has been closely tied to developments in the electronics industry ever since the development of the transistor. A good idea of how technical changes emanating from the semi-conductor industry have transformed user products is given in Table 1.8. This presents a "composite" index of changes in three performance variables - speed of operations; cost per operation and memory capacity for successive computer vintages introduced between 1951 and 1978.

TABLE 1.8

Computer Indices by year of Computer Introduction, 1951-1978

Computer	Year	Speed (Kops/sec)	Cost (Kops/$)	Capacity (Kbytes)	Index
UNIVAC U1	1951	0.27	7	8	0.011
IBM 704	1955	3.79	50	192	0.246
IBM 7090	1959	45.47	443	197	0.378
IBM 7094	1962	95.90	842	197	0.526
CDC 6600	1964	4,090.00	33,988	1,280	13.694
CDC CYB/76	1972	10,220.00	38,632	5,770	35.479
IBM 3033	1978	19,019.00	65,932	16,384	72.675

State-of-the-art factors

Factor	Units	Weight
X_1 : Speed	Kops/sec	$K_1 = 0.5$
X_2 : Cost	Kops/$	$K_2 = 0.3$
X_3 : Capacity	Kbytes	$K_3 = 0.2$

$$\text{Index} = 100\ K_1 \frac{X_1}{X_1^*} + K_2 \frac{X_2}{X_2^*} + K_3 \frac{X_3}{X_3^*}$$

X_1^* = minimum value of the parameter

X_1^* = 19,019 Kops/sec (IBM 3033)

X_2^* = 739,300 Kops/dollar (HP21MXM)

X_3^* = 16,384 Kbytes (IBM 3033)

Source: adapted from Soete and Dosi (1983)

The gains in performance and reductions in cost shown in the table have not surprisingly resulted in a continual growth in worldwide demand for computers of all sizes, as well as for associated peripherals and software. Table 1.9 documents this by showing the rate of growth of world production of computers by the developed countries between 1977 and 1981 and total production for the latter year. By 1990 total world production of computing equipment is expected to surpass $185 billion.

A particularly important feature of the computer industry has been the emergence of the microcomputer and the phenomenal growth of demand for these in the commercial, industrial and domestic markets. Priced at anywhere between $100 and $15,000, these systems have benefited enormously from improvements in components - so much so in fact it is becoming increasingly difficult to distinguish between the more powerful micros using 16 and 32 bit processors and mainframes and minis. After experiencing four years of 50-100 per cent annual rates of growth, the world market for microcomputers in 1983 was estimated at around $11 billion and is expected to rise to $33 billion in 1987 and $50 billion in 1990 (Bessant, 1983). At the level of individual countries, the business market for personal computers in the US was $6.3 billion in 1983, $10 billion in 1984, and expected to rise to $13.5 billion in 1985, while in Europe, 1985 sales are projected at $1.86 billion for France, $2.7 billion for West Germany, $1.27 billion for Italy and $2.25 billion for the UK (Electronics Week, 23 July 1984).

TABLE 1.9

Computer Production by Country

	1981 output value (US$ billions)	Growth rate (1978-1981)	World market share
United States	29.53	23.2%	57.7%
Japan	6.70	17.5%	13.1%
France	4.88	18.1%	9.5%
West Germany	3.50	13.3%	6.8%
Great Britain	2.33	12.1%	4.6%
Italy	1.19	30.4%	2.3%
Others	3.07	-	6.0%
Total	51.20	20.6%	100.0%

Source: adapted from O'Connor (1983)

In terms of industry structure, three features are important (and illustrative of trends in other parts of the electronics complex). First, US computer firms and IBM in particular, dominate the world industry. IBM alone controls 70 per cent of the market for mainframes and between 30-40 per cent for virtually every other product segment in which it is involved.(7) This situation will continue, though European companies have a strong domestic presence and the Japanese are expected to be moving into a position to mount a broad challenge to US supremacy in the near future. Second, the industry has also been characterized by the emergence and rapid growth of small, highly innovative firms - particularly in the most recent period with the introduction of the microcomputer. Such companies regularly record extremely high rates of growth.(8) Finally, the same high growth rates which have spurred the entry of so many new firms have also led many large established firms from other parts of the electronics complex to enter the market. Since late 1981, many large firms have brought out business/microcomputers with the explicit intention of capturing a major share of the rapidly growing demand for these products. Many of the 'big names' in components, office automation and larger computers are now involved in microcomputers such as DEC, ICL, Wang, Systime, Sony, NEC, Hitachi, Texas Instruments, Hewlett-Packard and IBM.

Not surprisingly, this has led to intense competition in an already fierce and crowded market. IBM's entry has been particularly significant - its personal computer captured nearly 30 per cent of the US market within months of its introduction. So far casualties have been high. Texas Instruments has pulled out completely (November 1983) with a loss of several hundred million dollars, Victor went bankrupt, and others such as Apple, Atari and Mattel all suffered serious losses in the US (though some firms such as Apple who initially suffered have now recovered and are fighting back to regain lost marketshare); while in the UK, firms such as Acorn, Dragon and Grundy have also suffered losses, with Acorn ultimately being forced into accepting a takeover by Olivetti to ensure its survival.

Finally, the trends towards convergence are very powerful in relation to the use of computers. The continued improvement of the microcomputer and associated developments in telecommunications will provide the impetus to a whole variety of future trends. They will involve a) the increasing domestic and commercial use of "stand alone" units, b) the merging of these stand alone units into integrated systems via local area networks and distributed processing systems within firms; c) the merging via the tying in of domestic terminals to subscription based interactive information systems; and d) finally the linking of local area networks into national and international information networks.

Some Third World Issues

There are two broad implications for the Third World in these developments. First the diminishing real price, increasing capacity and flexibility of the micro-computer has created a tremendous range of application opportunities which could yield substantial developmental benefits. Most of these remain latent however as the overall capacity of most Third World countries to articulate and then fulfil their demands with appropriate applications remains limited. Nevertheless, over the last few years there has been a rapid proliferation of microcomputer applications in industry, agriculture, services, health, education and the public sector. These applications can be quite sophisticated and often extend well beyond traditional electronic data processiing (EDP) activities. Rather than give examples in the text, we have in Appendix I compiled a table which gives details of different actual applications. The list is by no means comprehensive but is indicative of what is happening at ground level. What is particularly important to note about the information presented in Appendix I is the predominance of applications in relation to the agriculture and health sector in developing countries, once more emphasising the extreme flexibility of the technology (See also Munasinghe et al., 1985)

It is not really possible at this point to identify clear trends in the use of microcomputers in developing countries. If we consider the broader patterns of use of all computers (from the late 1950s through the 1960s) typically the first computers installed would have been mainframes often imported by subsidiaries of foreign companies for routine commercial clerical work (book-keeping, accounts, etc.) Government purchases of mainframes soon followed, and as Table 1.10 shows for Ghana and Bangladesh, the public sector remains the dominant user of mainframes in the less industrialised countries.

With the emergence of mini and then microcomputers this situation has changed significantly. For instance, the level of use of minicomputers increased significantly in the 1970s. In 1980 Brazil had 1880 minicomputers with the public sector accounting for about 50 per cent and most of the rest in services. In 1977 Mexico had 2250 mini and mainframe comuters of which 29 per cent were in the public sector, 29 per cent in industry and the rest in services. In Venezuela, 79 per cent of a total of 7435 computers in use were minis, again spread more or less evenly across the public and private sector (Rada, 1983). For microcomputers, numbers are much harder to come by but it seems that apart from the NICs their use is increasing even in the poorer countries (though of course it is still far below that of the developed countries). In Bangladesh, for instance, only six micros were known to be in use in 1980 - today there are more than 150. Similar trends must be happening elsewhere, with the most intensive usage being in services, (particularly banking and in the tourist sector) consulting firms, foreign entities (firms, embassies, etc.) and the government, education and health sectors.

TABLE 1.10 Recent Computer Installations in Bangladesh and Ghana

BANGLADESH User Organisation	Type of Computer	Year of Install.	GHANA User Organisation	Type of Computer	Year of Install.
Adamjee JM Ltd	IBM 370	1980	GOVERNMENT		
	IBM 1401	1968	Central Revenue Dept	ICL	1983
Agrani Bank	IBM 1401	1967	Ministry of Defence	Wang	1983
	IBM S/36	1984	Central Bureau of Statistics	Wang	1982
Atomic Energy Commission	IBM 1620	1964	Min. of Finance & Economic Planning	ICL	
	IBM 4341	1981	Acct/General Dept	Wang	1983
Bangladesh Bureau of Statistics	IBM 360/30	1973	National Commission for Democracy	Wang	1982
	IBM 4341/K01	1981	AGRICULTURE		
	IBM SYSTEM 34	1981	FAO/Ministry of Agriculture	Wang	1982
Bangladesh Bank	IBM 370/115	1980	EDUCATION		
Bangladesh Meteorological Dept.	IBM SYSTEM 34	1980	UST	IBM	
Bangladesh University of	IBM 370/115	1979	West Africa Exams Council	IBM	
Engineering & Technology			Uni. of Ghana - Medical School	Wang	
International Centre for	IBM SYSTEM 34	1980	- Finance Dept	Wang	1983
Diarrhoeal Disease Research	IBM 4341	1984	Inst. of Professional Studies	Wang	
Janata Bank	ICL (8K) Central	1967	SERVICES		
	Processor		Electricity (VRA)	Wang	1983
Project Implementation Bureau	IBM SYSTEM 34	1981	Electricity Corporation	Wang	1984
Population Control & Family	IBM SYSTEM 34	1981	Water/Sewerage Corporation	Wang	1983
Planning Division			Ghana Airways	Wang	1983
Bangladesh Biman (Air Line)	IBM S/34		Ghana Railways	ICL•	
FAO	IBM S/34		Bank of Ghana	IBM	
Hotel Sonargaon	NCR 8150	1981	SSNIT - HQ	Wang	1982
Banque Indosuez - Chittagong	NCR 8150	1981	SSNIT - DP Section	Wang	1984
BCCI - Dhaka (Bank) -	NCR 9020	1983	SIC	Wang	1983
Chittagong	NCR 9020	1984	BHC	Wang	1980
Banque Indosuez	NCR 9020	1984	Computer Services Ltd	Wang	1982/3/4
Dhaka University	IBM4341	1984	Foreign Embassy (USIS)	Wang	1980
			EXTRACTION		
			State Construction Co	ICL	
			Ashanti Gold Fields Co	ICL	
			MANUFACTURING		
			Valco	IBM	
			PRIVATE SECTOR - DISTRIBUTION		
			Taxaco	Wang	1983
			Goil	Wang	1980
			Mobil Oil	IBM	
			IBM	IBM	

Source: information provided by Dr Quazi Ahmed, Dacca Institute of Business Administration and Dr Stephen Adie, Ghana Investment Centre

Analytically, it would appear that exogenous forces (i.e. the drive for market share by foreign companies and personal mania for the latest technology) means that microcomputers are being introduced into an unstructured and unregulated environment. Well before users have become fully aware of their potential and before the necessary skills and support infrastructure have emerged, numerous firms set themselves up as local agents for imported micros and peripherals. For example, Bangladesh has a dozen such agents marketing personal computers from IBM, Radio Shack, Sord (Japan), NCR, Monroe, Alpha-Micro, Honeywell, ICL, Victor, Motosacoche (Swiss); Kenya has close to 20 and similar numbers exist in the Caribbean countries.(9)

This situation, which is common even in the poorest developing countries, creates a whole range of problems. The local agents operate in a sellers market and have little incentive to offer user training and service, or to ensure the appropriateness of the system being supplied. The many varieties of imported system and software packages are often inappropriate to users needs, and are being introduced in the absence of capabilities to use, adapt and maintain them. The resource costs of this situation can be quite considerable in the public as well as the private sector. For instance, a study of microcomputer use in the public sector in Mexico identified more than 350 different models (supplied by 120 local agents), many of them mutually incompatible. Poorly trained users and lack of maintenance mean that many of these systems are under-utilised or not functioning at all (Nochtieff and Lahera, 1982).

Another aspect of computer applications in developing countries which deserves mention is the overall nature of applications. We noted above that micros are increasingly being used in non-traditional activities. However, it is still the case that computers are overwhelmingly used for routine data processing applications. Rada's (1983) survey of users in Latin America showed that in Argentina, Brazil, Mexico and Venezuela 80 per cent or more of all computers are used for this sort of application. At one level this makes economic sense, given the low wage levels and lack of skills. However, it does suggest that there is a rapidly growing gap between developed and developing countries in terms of the level of computerization of economic activities and that could cause severe problems for the latter group of countries in the future. This is an issue we return to in later chapters.

Nevertheless, despite the constraints and the problems, the trend towards increasing diffusion is inevitable since the incentives for the efficient application of computers are very considerable. All of this points obviously to the minimum requirement which is that all countries need to develop policies regarding the import, sale and use of computers to ensure that such devices make the maximum contribution to development.

The second implication arising from the emergence of microcomputers relates not to their use but to the market opportunities which the technology has created. These opportunities fall into two categories - production of computers, peripherals and related components for export, and the development and production of systems for the local market. Turning first to the issue of exports, developed country based computer manufacturers have turned increasingly to developing countries as a source of low cost assembly labour (primarily for micros) and competitively priced components and peripherals supplied to both micro and mainframe manufacturers.(10) These initiatives have been undertaken both to supply developed country markets and, in the case of advanced Third World economies such as Mexico, Brazil, Singapore and South Korea, to serve domestic and regional markets as well.

The entry of foreign firms has been accompanied by the emergence of domestic producers, particularly in the Asian NICs and in Brazil and Mexico. For example, South Korea now has 13 computer producers with an annual output of 54,000 units. Singapore is pursuing the establishment of its own export oriented computer industry and at least one local company is preparing to manufacture and export portable microcomputers in direct competition with the Japanese (Lee 1983). Even without an original design capacity, some Asian firms operating in the "informal" sector of Hong Kong, Taiwan and South Korea have proved remarkably adept at producing passable copies of the Apple II for around $200.00. Though tariffs and poor software have prevented these machines from flooding the OECD markets, the success of these firms is likely to prove an important spur to efforts by other countries.

The same story emerges in the case of components and peripherals; and here the role of Asian NICs as computer component producers should be noted separately, since it highlights another set of product niches opened up by the boom in computer sales. Obviously enough rising demand for computers also means rising demand for computer-related peripherals and components. Some OECD countries such as the UK while strong in computers, are very weak in the domestic supply of peripherals and parts - in 1979 the UK trade balance in computers was $56 million in surplus while there was a $275 million deficit in peripherals (Nedo, 1981).

Astute observation of such market trends by the Asian NICs have led them to mount a massive assault on the parts and peripherals markets. In 1982 none of the big four producers, Singapore, Hong Kong, South Korea and Taiwan, were exporting more than $300 million of these products, yet all expect to export more than $1 billion worth in a few years time. Taiwan and South Korea are expected to become major suppliers of terminals, monitors and printers (South Korea already has 18 Cathode Ray Tube producers with annual production of 306,700 units and 9 printer manufacturers producing 23,000 units annually); Singapore aims to become a major supplier of disc drives (Ernst 1983, and Lee 1983). Second tier countries such as Malaysia have also entered into the components market (Malaysian Business, 1984).

The sourcing strategies of foreign firms and the export activities of local firms mean that a small group of developing countries have become important forces in the world computer market. This is clearly evident in Table 1.11 which shows 1977-1981 exports from selected developed and developing countries across four categories of data processing equipment - computers, central processing units, peripherals, and off-line data processing equipment.

In relation to the supply of systems for the local market, we have already noted that many opportunities exist. Local suppliers are extremely well placed to use detailed knowledge of local conditions and user needs to exploit the flexibility of computers to fill niches ignored by foreign suppliers. As we shall see, this is particularly true in relation to software application, but it relates to systems supply as well. Small but skilled teams can easily design small computers. Assuming an adequate market and government protection from import competition, such firms can use the well developed international market for off-the-shelf components to assemble and market their own design computers and peripherals.

This has already happened in many of the larger countries such as Brazil and Mexico. In both cases, the policy approach adopted was one of "market reserve" where access to the smaller computer market was restricted to local companies. In Brazil before 1977, there was almost no national computer industry (though IBM did assemble from imported components). Market reserve policies were established in 1977 and by 1980 five mini computer and about 20 microcomputer firms were responsible for 22 per cent of all mini computer (1880) and microcomputer installations (3000). Between 1978 and 1982 the total value of the mini and microcomputer market in Brazil grew from $144.8m to $608m. The percentage share of locally produced systems and of total consumption grew from 17 percent in 1978 to 80 percent in 1982. Though as Table 1.12 shows, the local industry did not acheive quite as spectacular a breakthrough in more expensive and more complex mainframe systems, there is little doubt in recent literature that the industry benefitted considerably from market reserve policies. (Erber, 1985; Tigre, 1983). A similar strategy was adopted in Mexico from 1980 and as Table 1.13 shows, the results have been equally impressive.

TABLE 1.11

Exports of Automatic Data Processing Equipment(b), from World, Selected Regions and Countries, 1977-1981
(US $ millions)

	All DP equipment	Digital computers	Central processing units	Peripheral equipment	Off-line DP equipment
1977					
World market economy	4338.3	192.1	104.7	284.8	25.7
North America	1271.3	-	-	-	-
United States	991.3	-	-	-	-
Canada	280.0	-	-	-	-
Europe	2806.4	151.0	78.4	220.1	10.5
Japan	153.5	40.9	26.2	64.4	11.2
Oceania	4.3	-	-	-	-
Latin America	88.2	-	-	-	0.2
Brazil	63.0	-	-	-	-
Argentina	24.0	-	-	-	-
Mexico	0.4	-	-	-	-
Asia	13.9	0.1	0.1	0.3	3.8
Hong Kong	0.9	-	-	-	-
Singapore	2.8	-	-	-	-
Rep. of Korea	4.1	-	0.1	0.2	3.7
1979					
World market economy	9325.9	1720.0	1595.2	449.8	188.6
North America	4002.1	688.0	756.6	1623.0	-
United States	3441.7	688.0	756.6	1623.0	-
Canada	560.4	-	-	-	-
Europe	4801.5	954.1	763.0	2513.9	161.0
Japan	372.0	72.4	71.7	202.5	21.5
Oceania	21.9	0.4	0.2	0.7	0.5
Latin America	104.2	1.6	0.8	97.4(a)	2.1(a)
Brazil	79.1	1.4	0.5(a)	71.5(a)	1.5(a)
Argentina	24.7	0.1	0.2(a)	20.4(a)	0.3(a)
Mexico	-	-	-	5.3	0.1(a)
Asia	23.2	3.2	2.0	10.0	3.8
Hong Kong	10.3	-	1.4	2.8	-
Singapore	7.2	-	0.2	2.9	1.1
Rep. of Korea	6.1	-	-	0.1	2.1
1981					
World market economy	11775.2	2009.7	1919.9	5546.7	170.6
North America	5835.8	961.6	1028.0	2517.9	-
United States	5042.9	961.6	1028.0	2517.9	-
Canada	792.9	-	-	-	-
Europe	4756.2	826.3	768.0	2303.1	130.8
Japan	878.0	206.7	76.1	561.3	26.4
Oceania	25.8	0.5	0.6	0.8	0.7
Latin America	199.5	2.6(a)	37.7(a)	127.5(a)	5.1(a)
Brazil	198.9	2.6(a)	37.7(a)	127.5(a)	5.0(a)
Argentina	-	-	-	-	-
Mexico	-	-	-	-	-
Asia	82.8	11.9	9.5	35.8	7.4
Hong Kong	35.0	-	8.4	19.8	-
Singapore	17.6	-	1.1	5.0	4.5
Rep. of Korea	14.8	0.1	0.1	10.9	2.9

Source: adapted from O'Connor

(a) Estimate
(b) 'Automatic data processing equipment' encompasses SITC, rev.2, item 752. 'Digital Computers' refer to SITC, rev.2, 7522; Central processing units to SITC, rev.2, 7523; Peripheral equipment to SITC, rev.2, 7525; off-line DP equipment to SITC, rev.2, 7528.

TABLE 1.12

Computers Installed in Brazil by Class* and Origin of Producer, 1978 and 1982 (US$ millions)

Class and producer	1978 Value (US$m)	A/D (%)	C/D (%)	1982 Value (US$m)	A/D (%)	C/D (%)
Classes 1-2		(17)	(83)		(80)	(19)
A - Produced by Brazilian firms	24.2			484.5		
B - Produced by foreign subsidiaries	-			7.0		
C - Imported	120.6			116.5		
D - Total	144.8			608.0		
Classes 3-6		(-)	(73)		(2)	(54)
A - Produced by Brazilian firms	-			48.3		
B - Produced by foreign subsidiaries	267.9			945.1		
C - Imported	735.0			1175.2		
D - Total	1002.9			2168.6		
Classes 1-6		(2)	(76)		(19)	(46)
A - Produced by Brazilian firms	24.2			532.8		
B - Produced by foreign subsidiaries	267.9			952.1		
C - Imported	943.0			1291.7		
D - Total	1235.1			2776.6		

Source: Erber (1985)

* In terms of 1980 average prices of a sample of equipment representing at least 80% of the computer population of each class: class 1: $20,000; class 2: $90,000; class 3: $180,000; class 4: $670,000; class 5: $1,900,000; class 6: $3,000,000.

TABLE 1.13

Impact of Mexican Computer Decree on Mexican Computer Industry, 1981-1983

	1981	1983
No. of Mexican firms: Micros	1	27
Minis	0	11
Peripherals	0	21
Total imports of systems/components	$250 m	$120 m
% of imports as systems	90%	36%
% of imports as components	0%	48%
% of imports as spare parts	10%	16%
Exports as % of imports	0%	25%

Source: Private communication, Electronics Commission of Mexico

Obviously the cases of Mexico and Brazil differ greatly from the conditions existing in the large majority of developing countries in terms of market size, existing technological capabilities and support infrastructure, the existence of a national policy, etc. Moreover, even the Brazilian and Mexican initiatives face a number of problems: the combined problem of the high cost and somewhat inferior quality of the units produced when compared to world norms; the need to shift start-up firms toward a self-sustaining growth path defined by local innovation and supported by the expansion of local supply of components; and the aggressive responses from foreign firms barred from what they see as extremely lucrative markets.(11)

For smaller, less developed countries the issues of market size, comparative costs, quality standards and existing low levels of technology pose very sizeable barriers for entry into hardware production. However, as we noted above, it is vital to distinguish between system and software design and engineering activities and hardware production when speaking of points of entry for most developing countries into computers. The examples of small firms and even university departments in many developing countries, large and small, successfully undertaking the design of computers, shows this can be done without access to domestic component production. Since there are very considerable externalities to be gained from developing even a limited system design and integration capability, the question of if developing countries should seek to accumulate skills in this area becomes more one of when they should do it and on what scale.

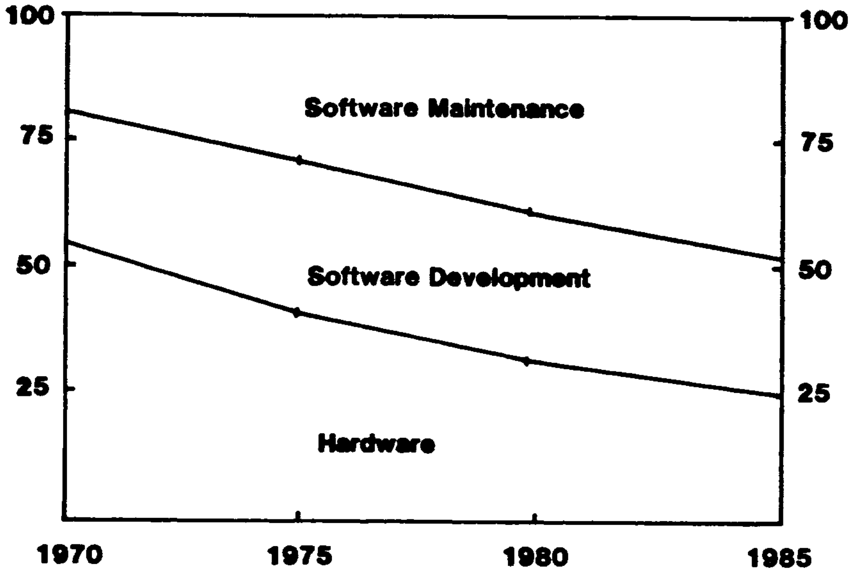
Hence the problems are largely policy issues relating to the size of the market, the role of imports, the nature of necessary government procurement and incentive policies, the selection of the appropriate point of entry and the provision of adequate supplies of trained personnel. We shall come back to policy issues raised by computer production for export and local markets in Chapter 5.

Section 5: Software

Discussions about microelectronics and computers inevitably concentrate on the hardware aspects of the technology. Yet it is software - the set of instructions which directs the computing system to operate in the designed way - that in many respects is the linchpin of the microelectronics revolution. The importance of software can be demonstrated in a variety of ways, not least of which is the obvious fact that software engineering is an essential input in the development and application of microelectronics devices and every system which relies on them. First, software costs are rising rapidly as a share of total system costs for the development, purchase and maintenance of computing systems. This is shown in Fig 1.4, and is a commonly recognised phenomenon that will continue into the future when software costs are expected to be equivalent to 90 per cent of total system developmental purchase costs.

Second, the proliferation and declining cost of computing systems has led to an enormous increase in the demand for software services and products that is outstripping supply by three to four times in almost every product category (Frank, 1984). Third, and related,there is a growing shortage of trained software personnel to deal with these rising demands - so severe is the constraint that NEDO (1980) argues that software personnel shortages of all types are the single most serious constraint on the diffusion of microelectronics and computer application in the developed countries. In the US alone, there is now an estimated shortfall of some 50,000 software engineers of different types. As Table 1.14 shows, this gap is expected to grow in virtually every category.

Figure 1.4: Trends in Software and Hardware Cost in Total Systems Costs



Source: O'Connor, 1985

TABLE 1.14

US Information Market, 1982

'Top ten' demand ranking mid-1982	Job title (and average most sought-after years of experience)	Rise in demand from mid-1981
1	Systems/software programmers (4.2 years)	+10.1%
2	Applications programmers (3.6 years)	+9.6%
3	Telecommunications specialists (2.6 years)	+8.9%
4	DP auditors (3.3 years)	+8.3%
5	Systems analysts (4.3 years)	+7.8%
6	Data base managers (9.0 years)	+7.4%
7	Software engineers (4.8 years)	+7.1%
8	Systems managers (6.5 years)	+6.7%
9	Software programming managers (5.9 years)	+6.2%
10	DP operations managers (8.1 years)	+5.8%

Source: Soete, 1983

Not surprisingly, the software market has grown exceedingly fast - much quicker than for most categories of computing systems. The US software market is growing at an estimated 35 per cent annually and will continue to do so until the end of the decade. Total software sales in the US were $6.7 billion in 1984. Applications software usually accounts for one half and systems software for just under one half of sales; with microcomputer software sales growing well in excess of 50 per cent per year (Electronics Week, July 1984). The software industry in developed countries offers an enormous variety of products and services to domestic, commercial and government uses. These include not only software packages of various sorts (i.e. systems, support, applications, operating and utility packages) but also data processing services, professional technical assistance, integrated systems data base services, and communication services. The industry is highly fragmented with some segments (such as mainframe systems software) being very large, and others (such as specific industrial applications) being very small and serviced by highly specialised firms. Most firms are small (under 50 people), with annual revenues amounting at most to $5 million, but there are a number of quite large companies, as well as over 60 firms in the US which have annual sales in excess of $100m (Frank, 1984). Commercial suppliers fall into one of 6 categories: - computer manufacturers, software houses, independent software producers, software brokers, turn-key system suppliers, and computer stores. Underlying these of course is a massive army of independent cottage industry type suppliers who provide the main commercial outlets with a steady stream of products.

Implications for developing countries

If software is important it obviously follows that the possession of the requisite type of software skills is an essential determinant of a firm's or a country's ability to succeed in exploiting the new technology. Such skills are an essential tool in the design of products from all parts of the industry - components, consumer electronics, computers, etc. Without a software capability there can be no real <u>indigenous</u> electronics production capacity in the country, nor can the country go very far in adapting available systems to its specific needs.

It must be stressed that the fundamental importance of software skills goes well beyond providing a base for the production of electronic products. Many countries, NIC and non-NIC alike, now find that they face considerable local demand for computing systems from both the public and the private sector. Frequently, the functional operating capacity of these imported systems (defined by their applications software) is not suitable to local needs. Availability of applications software skills creates the opportunity for local firms to adapt the systems, thereby increasing consumer gains and creating a new market opportunity. Already there are numerous examples in all types of developing countries of local firms which have successfully marketed "localised" applications software. Even more important than these static gains is the increasingly common process whereby these firms are able to build on their applications capabilities to move into the design and supply of total systems. One good example of this comes from Argentina. In 1977, 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. One of these was a Spanish language product which allowed Argentinian banks to computerize the onerous task of sending notifications to customers about changing interest rates on their fixed term deposits (between 500 to 3000 certificates per month per customer were required because of the hyper inflation). The firm was then able to move the design and assembly of peripherals and eventually microcomputer systems - by May 1980 it was selling 50 microcomputers and a variety of other hardware and software packages per month (Maxwell,1983). This example highlights the point that the development of an applications capability may be one of the best and most cost-effective ways through which smaller and poorer developing countries can begin to build up an electronics capacity.

The value to the economy of having a pool of skilled software personnel goes beyond the need to adapt the applications programmes of imported microcomputers to the data processing needs of the local business community. Much industrial equipment is in the process of being converted or redesigned to use microelectronic-based control systems. The ability of developing country firms to select, operate and maintain such equipment will also be heavily dependent on their software and electronic engineering skills. Though in the longer term industrial firms who will be using this equipment might be expected to develop their own capabilities, initially they will have to draw on the electronics sector itself as a source of skilled manpower to facilitate its assimilation. In turn some groups in the electronics sector will tend to specialise in providing services to particular sectors. Software skills developed as the electronics industry evolves will be the reservoir which will feed this process of diffusion throughout the economy.

All of these factors underlining the crucial role played by software virtually dictate that one of the key criteria that will determine a country's ability to develop an independent electronics capacity will be the level and nature of its software skills and the country's commitment to developing these further. This suggests in turn that significant gains will accrue to the economy from explicit investment in the development of software and electronic-engineering skills either via separate educational initiatives or as part of projects designed to increase the production capacity of the electronics sector. The policy issues associated with building up software capabilities in the Third World are discussed in Chapter 5.

Export prospects

One of the new conventional wisdoms in the field is that developing countries are well placed to export software and computer services to the developed countries. The rationale lying behind this argument stems from the above discussion of industry characteristics and rests on four points: First, the large demand for products and services is outstripping the supply capacity of the industry in the advanced countries. Second, the highly fragmented market for products means there are many market niches where small firms can gain entry provided they have a reliable product. Third, the skill barriers to entry are really quite low. The skills necessary to perform simple data processing or to write standard business applications are fairly limited - programmers need only a good high school level education. Fourth, capital costs are low as well, with an initial investment of perhaps only $50,000 being necessary to get a firm started. The final advantage enjoyed by developing countries stems from the rising costs of software faced by both system users and system/software producers. These rising costs are due to scarcity induced high wages for programmers, the increasing complexity and therefore greater cost of the software being designed; and the relatively limited amount of time that can be devoted to writing new programmes (due to the burden of maintenance work).

In contrast developing countries enjoy a traditional low wage competitive advantage in software production which means that unit costs of production can be from three to ten times below that of developed countries. For instance the average yearly wage of a programmer is reckoned to be $2700 in India, $5600 in Malaysia, $5400 in the Phillipines, and $1800 in Sri Lanka. Taking the India example one needs to add in additional wage related costs of $2100 and $4020 for overheads to arrive at an annual cost per programmer of $8,820 (UNIDO, Microelectronics Monitor No. 3, July 1982, p.37).

Since the average starting salary for a graduate programmer in the US in 1984 was $20,000, there does appear to be an a priori case for developing countries to seek to export their software. So far, however, the level of export activity is still limited compared to the size of the market and the revenues being recorded by firms in the developed countries, but countries such as India and Singapore are experiencing a reasonable degree of export success.

Undoubtedly some of the smaller Asian countries are begining to show signs of increased software export activity. In the policy discussion in Chapter 4, for instance, we shall review the policies that have been adopted by Singapore in this regard. However, despite the apparent advantages developing countries might enjoy in gaining initial access to export markets there are countervailing trends which should be noted:

First, the high costs of producing software and the shortage of programmers have, not unexpectedly, led the industry to search for ways to overcome the software bottleneck. They include the development of a wide variety of programming tools, the use of new languages, and massive training programmes. These efforts are not expected to provide overnight solutions and the situation described above is expected to continue until at least the end of the decade. However, because the pressures to achieve major gains in software productivity are so great, substantial cost reductions stemming from the above efforts should begin to occur by the early 1990s. This trend suggests that for the next ten years or so, the market opportunity in the OECD countries which has been created by rising demand will remain open and could be filled at least in part by Third World exports. These opportunities will be complemented by increasing software markets in the developing countries themselves over the course of the decade. However, over time this software export "window" may become progressively smaller as the above efforts for increased supply begin to bear fruit.

A second problem arises in relation to the nature of the software products that developing countries will be able to export. At the moment, existing Third World software exports are almost all tied to the operations of TNCs who subcontract only relatively simple data processing tasks to their offshore locations. There are possible benefits arising from this entry route - software subcontracting may provide the same sort of springboard which NIC firms used to launch their independent hardware capability. Policies need to be in place which encourage this. At the same time, developing country firms must try to build up their own links into the OECD software market by developing an independent and marketable subcontracting capability or by producing applications packages for outright sale.

This may well be more difficult than it seems on the subcontracting side; it is simply not yet clear how internationally "divisible" software production can be, particularly where more complicated programmes are involved. Transmitting detailed specifications via the telecommunication network and getting the tasks successfully carried out by the subcontractor is likely to be a very difficult business as it requires extremely close coordination between all groups involved. More information is needed on current developments to assess the possibilities in this area. Where applications programmes are concerned, the programmer must have a detailed knowledge of the characteristics of the product in order to be able to produce efficiently workable software that precisely fits user needs. A great deal of face-to-face interaction is required in the process of producing applications software for individual customers. Producing packages for industrial applications may require less face-to-face contact but much more detailed knowledge of the specific product, process and equipment involved and the various ways in which individual firms use the technology. To get this sort of knowledge will require a good deal of 'on the spot' involvement with the industry.

Developing country firms suffer a "distance" problem in both these cases which obviously inhibits the feedback process which is so crucial during the development stage in software production. Unless Third World firms can find a way around the distance/feedback problem, they may find it impossible to make major inroads into the more sophisticated and more lucrative end of the market. There are possibilities. One is to take another full advantage of the rapid strides that are taking place in telecommunication and computer technology. Another is to set up subsidiaries inside their main export market. Setting up some sort of local presence in OECD countries might also allow Third World firms to gain access to the maintenance and service market from which they are effectively excluded at the moment, but which is reckoned to be the largest and most profitable of all software markets. It might also overcome user reticence to purchase software products from Third World vendors because of "quality" concerns as well as providing the basis on which firms can establish an efficient marketing network. It is therefore encouraging to note that a small but growing number of firms from the Asian NICs and second-tier countries are in fact establishing operations in Silicon Valley and elsewhere in the U.S.

Other software trends, such as increasing concentration in some market segments, and the increasing use of "firmware" (see Ernst 1983 for a discussion), though still only at an early stage, also need careful monitoring. All of these factors suggest that developing country software firms will have to be very flexible and highly sensitive to market trends in order to be successful exporters. The balance appears to be in their favour at the moment - but with the little information available on the precise nature of their current export experience and of the technical and economic conditions which have to be met, it is hard to judge how much of the potential gains which are so widely talked about can be realistically captured.

Footnotes to Chapter 1

(1) By electronics complex we refer to the cluster of industries which includes components, computers and peripherals, consumer electronics, telecommunications, industrial electronics and professional electronics.

(2) Electricity powered technologies proved essential to the imposition of "Taylorism" and "Fordism".

(3) The market share of 64K Random Access Memory (RAM) chips only introduced over the last few years is already being eroded by 256K chips.

(4) RAMs have increased in density from 1K or 1027 bits in 1971 to 256K or 262,384 bits in 1985.

(5) This is similar to what the Japanese achieved in colour TV production where they were able to reduce the number of components and greatly increase their use of automatic insertion technology. The net result was a considerable degree of penetration of the US and European markets on the basis of a lower cost but higher quality product.

(6) The UK consumer electronics industry has been pressing the UK Government to impose tariffs on colour TVs in order to give local producers enough time to bring out their new much more competitive products.

(7) High degrees of concentration are in fact a common feature of other segments of the electronics sector.

(8) All US firms which registered an annual growth in sales of over 40 per cent from 1976-1980 were involved in some segment of the electronics complex. All could be classified as small highly innovative firms and 26 of these were computer firms (Freeman, Clark and Soete, 1983).

(9) Information provided from personal contacts of the author.

(10) For instance IBM purchased $50m worth of components from Singapore in 1983 and $35m worth in 1982 from Taiwan (Ernst, 1985).

(11) IBM has been placing extremely heavy and high level pressure on the Mexican government via the US government to force Mexico to lift its ban on IBMs involvement in the local market.

CHAPTER 2

CURRENT APPLICATIONS AND FUTURE TRENDS IN THE USE OF MICROELECTRONICS IN INDUSTRY

Almost every day more evidence emerges to show that industry and services in the developed economies are being profoundly affected by the application of microelectronics. New products are marketed with bewildering rapidity. Firms throughout the OECD, despite the recent recession, have begun to invest heavily in automation technologies which promise substantial improvements in productivity. The notion that industry must "automate or liquidate" is becoming more and more firmly entrenched in corporate and government thinking.

The relative speed with which firms and countries adapt to and exploit information technology within industry is now viewed as the key determinant of international competitiveness in the future. Nevertheless, there are still major uncertainties over the length of time it will take for the industrial sector to adapt fully to the new technological "paradigm" being defined by microelectronics. As we showed in Chapter 1, diffusion has been rapid within the electronics complex and this has been accompanied by major structural changes there. In the industrial sector though, the diffusion process has been much more uneven. Certainly some sectors have already been profoundly influenced. One need only consider the revolutionary changes in automobile assembly, in printing and in a variety of mechanical engineering sectors to see that the "future" has already arrived. However, in many other sectors, diffusion of the technology is taking much longer than was originally anticipated. Clothing manufacture is an example - design and other pre-assembly activities have been radically transformed, but the clothing assembly process has been barely affected as yet. Overall, this rather uneven performance and the continued prospects for gradual rather than overnight change mean that the diffusion process in some sectors must be measured in terms of decades rather than years.

The diffusion issue is further complicated by the fact that the technology and the mode of its introduction in the industrial sector is evolving rapidly. As we saw in Chapter 1, the digital nature of microelectronics greatly facilitates the attainment of a degree of systems integration not previously possible with analogue control devices. The economic and technical advantages of integration in turn compels producers and users to pursue the process further. The current use of CAD systems, numerical control and computer based process controllers in "stand alone" function specific applications really represents only the "first generation" of industrial applications of microelectronics that does not involve a high degree of integration. For instance, the use of computers in production is independent of their use in design, which in turn is independent of their use in inventory control, and so on. Yet due to the inherent logic of the technology, the locus of technical change and innovation has increasingly begun to take on a "systemic" character. Formerly isolated islands of automation are being linked together at progressively higher levels of integration. The effects of this will be far more significant than anything most firms have experienced so far as a result of microelectronics. Whereas stand alone 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.

Both of these aspects of the diffusion process (uneven penetration and evolving best-practice frontiers) have important policy implications for developing countries which we discuss later in Chapter 3. The point remains, however, that the progressive penetration of microelectronics through industry is as inexorable as were the earlier technological revolutions which accompanied the industrial diffusion of steam power and electricity. The key facilitating factors lie in the technology's low unit cost, flexibility and applicability in any production process where the collection, storage, processing and transmission of information is involved. In the light of the enormous scope this opens for the use of information technology in industry, one can only agree with the following observation that:

> "It is indeed difficult to think of an industry or occupation which will not be affected by microelectronics. The former Conservative Party spokesman on technology, Ian Lloyd, could think of only a few; among them were the makers of top hats, handloom weavers in the Outer Hebrides and psycho-analysts. He may well have been wrong about at least two of these."
> (Freeman, Clarke and Soete, 1982)

In this chapter we will try to give an overview of the main trends in the application of information technology to the manufacturing and service sectors in different types of economy. This is by no means an easy task since the scope of applications is so very large and does not recognise traditional definitions and boundaries. Most of the evidence presented will relate to the experience of the advanced industrial economies, though wherever possible material taken from Third World experiences will also be used. This is necessary for a number of reasons. First, most of the relevant developments are taking place within the industrial economies and only a limited amount of information is available on what is happening in the Third World. Second, the pace and direction of microelectronics based technical change in the North will inevitably be an important determinant of the impact of the technology on the Third World. The rate of diffusion and the scale of productivity improvements attained will define the room for maneouvre for countries seeking to compete internationally. Developing countries which introduce microelectronics related innovations (MRIs) into industry will, for quite some time, import these from the industrial countries. Third, the experience of industrial countries in introducing MRIs will provide a useful guide as to the problems likely to be encountered should firms in the Third World seek to follow a similar path.

Finally, the relationship of developing countries vis-a-vis industrial applications of microelectronics is fundamentally different from their role in the electronics complex. In the latter case, a number of countries are already major exporters and the prospects for remaining in the "game" are relatively favourable. Where industry is concerned, most Third World countries stand much further away from the technological frontier. Few countries are currently major producers or users of industrial products and processes incorporating microelectronics and information technologies. Consequently, they are forced into a position of having to respond to externally induced changes in the production and competitive environments in which they operate.

Areas of Application

In the industrial sector, the nature of microelectronics means that the technology can be introduced into the following functional categories which are present in most activities:

- the use of information in production management and firm administration;

- the area of product design and process specification;

- the controlled movement of materials and components between work stations;

- the positioning of components to allow machining;

- the control of process variables such as temperature, pressure, time, etc., and the monitoring of the production process;

- the cutting, mixing, moulding and shaping of materials;

- the assembly of components and sub-assemblies;

- the testing and inspection of products and the manufacturing process for quality control and maintenance purposes.

Given this flexibility and the economic advantages associated with its use it is not surprising that the technology has already been introduced into a wide array of products and processes, and as can be seen from Appendix II (which contains only a very limited set of examples), these applications cut across virtually every sector in a way that defies simple categorization. Despite the apparent profusion of applications, by far the most important developments in industrial technology stem from the emergence of a family of automation technologies built around microelectronics and computer technology. These technologies are applicable in all aspects of the production process - in the area of design where the parameters defining the product to be produced and the production process itself are specified; in the manufacturing phase proper where inputs are transformed into output; and in the area of management and control where design and manufacturing are planned and co-ordinated and the firm's commercial strategies are formulated.

Computer-aided design (CAD) is the principal automation technology developed in the design phase of the production process. In the manufacturing sphere, computer numerical control technology is one of two key automation technologies. Originally developed for use with machine tools, it now provides the basis for the control and co-ordination of industrial robots, automated transfer lines and many other types of machinery. Also in the manufacturing sphere, a wide variety of industrial process control systems have emerged which essentially allow real-time monitoring and control of the production process. Finally, in addition to the advantages offered by plant-level control systems, many other aspects of the management function are being transformed by the development of office technologies which allow the integration of information flows relating to production, finance, marketing and administration.

In Section 2 we present a brief description of these technologies and review the process of their diffusion and application across sectors and countries. We have decided to focus our discussions on these technologies (rather than on a sectoral review) because of three factors. First, like the microprocessor itself, these technologies are generic and can be applied to functions which are common to a wide number of sectors and production processes. Therefore, their continued development and diffusion is stimulating further rounds of change in ever larger numbers of downstream users. Second, they are major innovations in their own right and their use as stand alone devices yields quite dramatic gains which can have profound effects on the economics of production and the structure of the firm. (This is discussed in Chapter 3.) Third, and most importantly, they are also building blocks which can be combined together to allow much higher levels of automation, linking together what were previously disparate spheres of production, in a way that only a few years ago was still in the realm of fantasy. In Section 3 we present a conceptual discussion of the automation process; this provides a context for reviewing future trends in the industrial use of microelectronics, which is done in Section 4.

Section 2: Automation Technologies: Characteristics and Trends in Application and Diffusion

Computer-aided-design (CAD)

The development of CAD technology has been one of the most important industrial applications of microelectronics. This arises from two characteristics of the technology. The first is the profound impact that CAD can have on the design function. CAD systems have an interactive-graphics capability, which means that all the features of the product, part, or system being prepared can be graphically represented in three dimensions. The designer can change any parameter of the design and receive an instant response (interaction) from the computer on how that change affects other elements of the design, such as its force, deflection or stress characteristics or its overall performance specifications; even the changes in production costs can be calculated. In addition, the design can be rotated on any axis to view it from different angles, and if a multicomponent product, it can be 'exploded' to show how all the parts fit together (see Kaplinsky, 1982 for further details).

Once the designer decides upon the optimum design, it is stored in the system's memory. On this basis, all of the subsequent activities involved in generating the design necessary to allow production to proceed can be based on the stored model - working drawings can be instantly reproduced and amended if necessary, the parts list prepared, bought out parts described, etc. All of the time-consuming paper-bound stages (often involving different skilled people) can be eliminated, design times greatly reduced - from days or weeks to hours - specifications produced much more accurately and products designed to much finer tolerances than was previously possible. In some cases, the use of CAD allows the design of products that were never possible before (e.g. new aeronautical shapes) and there are now a number of products that cannot be produced without CAD because of their great complexity (e.g. nuclear power stations or VLSI chips).

The functioning of a CAD system is predicated upon the transfer of a very wide range of firm-specific information relating to the product being designed, from its physical embodiment in the designer, and in his parts list, design equation and principles, unit costs, performance, specification, etc., into the central processing unit (CPU) and memory banks of the system. The system's application programmes then use the designer's instructions to perform whatever function is required, from drawing a straight line to performing complex calculations. Applications extend to any activity which involves draughting, design and engineering skills, and as might be expected, the sectoral applications are considerable in shipbuilding, process plant design, machinery production, aerospace, automobiles, electronics, printing and communications, garment and textile production, etc. The wide variety of CAD applications to different tasks is shown in Table 2.1:

All of this is understandably impressive but it tells only part of the story. The second and much more important implication of CAD technology is that once in place, one of the major obstacles to automation in subsequent stages of production is removed. The electronification of design which is manifested in CAD technology (i.e. reduction of all design information to numerical coordinates which can be stored and transmitted electronically) means that all of the subsequent manufacturing activities - parts ordering and inventory, materials handling, manufacturing proper (material transformation) testing, and distribution - can be based on the information generated and stored at the design stage. Downstream machinery equipped to receive electronically transmitted instructions can be directed and controlled with the minimum of human intervention.

TABLE 2.1

CAD Task Applications

Product Planning	Design & Analyses	Drafting Documentation	Production Programming	Manufacturing Engineering	Industrial Engineering	Facilities Engineering
*Product Simulation *Mission Analysis *Financial Modelling *Project Simulation *PERT	Mech. * Concept Design *Surface Definition *Detailed Layout *FEM *Thermal Analysis *Tolerance Building Checking *Interferences Checking ELEC. - *Gate Arrays *Placement & Routing *Micro/PC Design *Check Plot *Design Rule Checking CONST. - *Piping ISOs *P & ID *Plant Layout *Street Detailing *FEM	Mech. *Detail Drawings *Assembly Drawings *Bill of Materials *Report Generation *Technical Publication ELEC. - *Schematics *Check Plots *Net Lists *Bill of Materials CONST. - *Schematics *Drawings	Mech. *N/C Tapes *Cutter Location Verification *Parts needing Elec. *Photo Plot File *Pattern Generation	*Redesign for Manufacturing *Tools & Fixture Design *Process Planning	*Labour & Machine Time Standards *Machine Utilisation Analysis *Process Control	*Plant & Equipment Layout *Equipment Design
				Process Planning	**Material Management**	**Reliability Engineering**
				*Equipment Parts Inventory *Automated Warehousing *Machine Monitoring *Manufacturing Planning	*Rough Cut Resource Modelling *Parts and 30M *Routings & Work Carriers *Material Issues & Records *Inventory Balance Management *Work Order Control *Purchase Order Tracking *Materials Requirements Planning *Standards Product Costing	*Quality Control *Coordinate Measuring *Failure Analysis
						Production Scheduling
						*Finished Goods Inventory *Demand Forecast *Order Backlog Control *Production Schedule Modelling

Source: Microelectronics Monitor (October 1983)

> "Once you accumulate knowledge in the design stage on the geometric definition of a part, you can then easily programme a robot or a machine tool to handle that part, and put it together." (Business Week, 1981, p.49.)

CAD paves the way for the "factory of the future". The issues this raises will be discussed in Section 4.

Evolution and diffusion

CAD technology was originally developed within the defense and aerospace industries in the US in the 1950s and 1960s, but by the early 1970s it had begun to spread to the electronics sector where it quickly became an essential tool in the design of integrated circuits (ICs) and computers. By 1976 annual sales stood at $80 million, but subsequently they took off at an annual rate of 85 per cent, so that by 1980 they had reached nearly $1 billion and reached close to $5 billion by 1985 (Kaplinsky, 1982).

By mid-1982 there were approximately 10,000 CAD installations around the world (a figure expected to grow to 27,000 by 1986). Of these, approximately 50 per cent were in the US and 35 per cent in Europe (Edquist and Jacobsson, 1984). The extent of use of CAD systems in the Third World is not known precisely but according to one study, of some 8000 installations, only 32 were in developing countries. Many of these were being used by TNC subsidiaries involved in the petroleum, automotive and electronics industries - and one system was reportedly sold to Zaire without any software! (Kaplinsky, 1982).

No doubt there are a large number of CAD installations of various sorts among domestically owned firms in developing countries that are not captured by the above figures. Some of the large US CAD suppliers such as Computervision have set up distributors in Singapore and Hong Kong to sell systems directly to the expanding market among Asian electronics firms. Use in other countries is probably as yet limited to the NICs and in sectors such as shipbuilding, automobile and component manufacturing, metal works and consultant engineering. Out of the six systems installed in Brazil in the last three years, four are used by engineering firms and two by electronics firms (Stenmer and Ferreria, 1983). Table 2.2 shows the current level of use and distribution of CAD systems in Argentina. As the table shows, the mix of applications for which the systems have been used is very varied, and not all that far removed from the way the systems are used in the developed countries.

Use of CAD technology will undoubtedly expand among the NICs, particularly among the larger firms able to afford the considerable capital sums involved in acquiring the equipment - the Argentinian system will cost between $500,000 and $1,500,000. On a straight competitive cost basis the potential market is probably quite large. Kaplinsky (1982) has shown that the costs of running the system can be justified if draughtsmen's wages are above $6.00/hour. However the actual rate of diffusion will probably be well below the potential until capital costs decline (which they have been doing consistently) and more importantly until the suppliers undertake a concerted effort to penetrate markets in the Third World. For the moment they are fully occupied in dealing with an OECD market expected to grow at a rate of 40 per cent a year until the end of the decade.

In terms of the pattern of diffusion across sectors, the concentration of users in the electronics, aerospace and automative sector remains high - but the technology is inexorably making its way into other sectors, particularly mechanical engineering, architecture, clothing and construction. Table 2.3 shows the pattern of sectoral use of CAD systems in the UK. Here the concentration in the electronics industry is evident, with the four leading users being electronics-related. Edquist and Jacobsson (1984) report that a similar pattern of distribution can be found in Sweden.

TABLE 2.2

Diffusion of CAD/CAM in Argentina

Enterprise	Activity Branch	Sector	Work stations	System	Nationality of the supplier
1	Metal working capital goods	Private	31	CADAM computer-vision ANVIL 4000	USA
2	Consortium with metal working partners. Engineering	Private	16	CADAM IBM	USA
3	Consortium with metal working partners. Engineering	Private	10	Intergraph	USA
4	Shipyard	Private	6	Unigraphics	USA
5	Engineering	Private	4	CADAM IBM	USA
6	Metal working	Private	4	G-Sic	USA Argentina
7	Cartography	Public	3	Intergraph	USA

Source: adapted from Chudnovsky (1984)

Kaplinsky (1982) made an interesting attempt to compare the likely pattern of CAD diffusion in the OECD countries with the pattern of manufactured exports from developing countries. Using US data from the 1970s on the design and draughting intensity of different sectors (which now seriously understate the dispersion of the technology), he found that CAD systems were likely to diffuse in precisely those sectors where export growth was high in the 1970s and where Third World countries plan to specialise in the 1980s. His findings are presented in Table 2.4. Given the very significant gains in labour productivity and lead time which the use of CAD confers, unequal diffusion between developed and developing countries could erode the international competitive advantage of Third World firms operating in markets where their competitors are using the systems.

TABLE 2.3

Main Users of CAD in UK, 1981

Industry	Number of firms using CAD	Percentage share of total number of firms using CAD
Radio, radar and electronic equipment	(19)	13%
Radio and electronic components	(18)	25%
Electronic computers	(12)	33%
Telegraph and telephone equipment	(12)	41%
Aerospace equipment	(11)	48%
Industrial plant and steelwork	(10)	55%
Other (mechanical) machinery	(10)	62%
Motor vehicle manufacturing	(9)	68%
Electrical machinery	(5)	71%
Mechanical handling equipment	(5)	74%
Other industries	(38)	100%

Source: adapted from Arnold and Senker (1982)

This point is partially borne out by research into the effects of automation on international competitive advantage in the clothing industry - an industry of obvious crucial significance to a large number of Third World countries (See Hoffman and Rush, 1986). CAD applications have been developed for use in the clothing industry which virtually eliminate the need for highly skilled graders and markers and allow very substantial reductions in material use. This latter effect is particularly important because material accounts for 50 per cent of the total cost of a garment. For many large clothing firms, CAD systems have become an essential technique which has greatly enhanced their competitiveness.

Even though the systems are expensive (ranging upwards from $200,000 for the basic unit), diffusion has been rapid, particularly in recent years, when annual sales increased by 40 per cent. By 1982 more than 700 CAD systems had been sold and nearly 50 per cent of the clothes produced in the US (worth $26 billion) came from firms using CAD systems. In contrast less than 20 systems have been sold in the developing countries, primarily in the Asian NICs and to domestic producers in Latin America. Although the potential Third World market may be upwards of 50 to 100 firms, the high capital, output and skill requirements mean that diffusion will be slow in the short to medium term, and a large share of firms could be excluded from using the technology.

The competitive problem that this pattern of uneven diffusion creates will be compounded in the future by the trend towards integration between CAD and other automation technologies used in subsequent stages of the production process. This is already happening in clothing with the introduction of CNC controlled cutters and it will eventually extend to the assembly stage. At this point, the systems level gains from integration will greatly improve the price competitiveness of developed country manufacturers vis-a-vis Third World exporters. Examples of this will be given in Chapter 3.

TABLE 2.4

Developed Country Imports of Manufactures from Developing Countries in relation to Design and Draughting Intensity

	Value $ million 1970	Value $ million 1978	Growth 1978/1970	Rankings (N = 15) Value (1978)	Rankings Growth	Rankings Draughting intensity	Rankings Design intensity
Major traditional manufactures							
Semi-finished textiles	1,815	9,610	5.3	1	13	11	11
Clothing	1,181	9,502	8.1	2	10	12	14
Shoes	151	2,033	13.5	7	6	14	13
Major higher-technology manufactures							
Chemicals	588	2,282	3.9	5	15	9	6
Metals and metal products	319	2,223	7.0	6	12	10	9
Machinery except electrical and business	81	1,136	14.0	8	5	4	3
Electrical machinery	372	4,463	12.0	3	7	1	1
Business machines	81	600	7.4	12	11	2	5
Scientific instruments	24	359	15.0	13	3	3	4
Motor vehicles	23	603	26.2	11	2	8	10
Aircraft	18	737	40.9	10	1	6	2
Shipbuilding	40	355	8.9	14	9	5	8
Consumer electronics	214	2,391	11.2	4	8	*	*
Total other manufactures	401	2,922	7.3				
Total major traditional manufactures	3,330	22,095	6.6				
Total major higher technology manufuctures	1,762	15,178	8.6				
Total manufactures	5,493	40,195	7.3				

Source: Kaplinsky (1982)

Computer numerical control (CNC) systems

The implication of the application of CNC systems to industrial equipment can best be portrayed with reference to their use with machine tools. The economic importance attached to the production and use of machine tools (and more generally of capital goods) hardly needs to be emphasized. They make a key contribution to capital formation and to raising the productivity of investments. Moreover, their widespread use acts as an important source for the diffusion of technical change in industry and for the technological transformation of society as a whole. Hence the recent dramatic changes in machine tool technology due to microelecronics are of absolutely central importance to developing countries; not only because of their already wide use in production and as a source of exports for some countries, but equally because the trends occurring in the sector provide a glimpse of future developments across the whole category of capital goods.

Numerical controlled machine tools, developed initially in the early 1950s, are machines which drill, grind, cut, punch or turn according to the instructions contained on a pre-determined numerically based programme recorded on magnetic tapes or perforated tapes or cards. In the early vintages, conventional electronic components, including dedicated ICs, formed the control system hardware. Although this allowed automatic control of previously mechanically/manually controlled machines, it nevertheless proved an expensive, bulky and unreliable way of directing single function machine tools. Any extension of capabilities required expensive hardware alteration and the machines themselves were fairly limited in their range of application. All of these factors combined to limit greatly their use in industry and allowed conventional machine tools to capture a very large percentage of total sales (Jacobsson, 1985).

The advent of microelectronics has dramatically changed the picture. Conventional hard-wired control systems have been replaced by cheaper and more reliable mini computer and microprocessor based control systems which have much greater performance capacities. This has facilitated the complete redesign of the control system, allowing it to perform all of its previous functions - tape reading, tape translation, tool sequencing, etc. - more accurately, more quickly and more reliably. Programming is made much easier as programmes can be stored and altered to include more features such as adaptive control. This is a means of process optimization by which the control unit senses changes in process variables (cutting forces) and operating parameters (such as feed rate), and responds according to a specific control strategy. In addition, the control capacities of the controllers are greatly enhanced - more types of movement can be handled, tool and part movements can be controlled with absolute accuracy to allow the production of optimal parts, while automatic tool replacement allows down-time and set-up times to be reduced substantially and faults to be diagnosed.

More significantly, the machine tool itself can be redesigned around enhanced CNC capacities, thereby greatly improving all operational parameters. This applies not only to individual machine tools but also greatly facilitates the design of integrated machine tools such as machining centres which combine previously discrete machining operations into one machine. As we shall discuss in Chapter 3, benefits accrue in many areas - significantly increased labour and capital productivity, quicker turnaround, better product quality, reduced working capital requirements, etc. The CNC basis for controlling machine tools also implies two other significant developments. First, when used in conjunction with CAD systems, it is now possible to feed the instructions generated there directly into the CNC machine tool itself or on to punched tape without using human programming skills. The linkage of CAD systems and the CNC tools (one version of CAD/CAM systems) is spreading rapidly and represents a radical change from previous practice, since two formerly discrete areas of activity - design and manufacturing - can now be integrated. Secondly, the use of CNC also means that a central computer can be used to control simultaneously a number of CNC machine tools and these can now be fully integrated into a continuous production process in place of the batch production method previously characteristic of these tools. These developments are discussed in Section 3.

Unlike other automation technologies in use in the manufacturing sphere such as robotics and hierarchical process control, machine tools are now a relatively mature product that entered the growth phase of the cycle in the mid 1970s. Thus, CNC machine tools in general and CNC lathes in particular (the most widely used CNC machine tools) have begun to be produced in very large quantities, allowing manufacturers to gain scale economies (Jacobsson, 1985).

CNC machine tools have, as a result, become increasingly competitive with conventional machine tools. This can be seen from Table 2.5, which compares the unit prices of conventional lathes and CNC lathes in Japan. What the table does not reveal are the tremendous improvements in performance that have accompanied the decline in prices and which have significantly enhanced the competitiveness of these techniques. As a result, the diffusion of CNC machine tools has occurred very rapidly in recent years. Taking the case of CNC lathes as an example, while the average share of CNC lathes in total investment in lathes was around 20 per cent for the OECD as a whole in 1975, in 1982 this had risen to 54 per cent on average and to 58 per cent in Japan by 1982 and 60 per cent in the US, and to 78 per cent in Sweden by 1981 (Jacobsson, 1985). This trend can also be seen from the OECD production figures for different categories of machine tools, as shown in Table 2.6.

TABLE 2.5

Price Ratios of CNC Lathes and Conventional Lathes in Japan, 1974-1981 (million yen)

	(1) Conventional lathes price per unit	(2) CNC lathes price per unit	(3) (2)/(1)
1974	2.07	17.20	8.32
1976	2.43	11.75	4.83
1978	2.59	11.10	4.28
1981	3.08	8.93	2.89

Source: adapted from Jacobsson (1985)

TABLE 2.6

Share of NCMTs in Total Production of Selected Metalcutting Machine Tools in OECD* 1976 and 1982

	1976		1982		Growth of production in 1976-1982 (in %)
	US$m	%	US$m	%	
Boring machines					
NCMT	92	35	297	57	223
conventional	171	65	226	43	32
Milling machines					
NCMT	145	23	633	53	337
conventional	493	77	557	47	13
Drilling machines					
NCMT	34	13	93	34	173
conventional	229	87	178	66	-22

Source: adapted from Edquist and Jacobsson (1985)

* USA, Japan, FRG, France, Italy and UK.

In considering the distribution of diffusion across sectors, the general machinery category [ISIC 382] generally accounts for nearly 50 per cent of all users in the OECD countries, followed by transport machinery and the other sectors listed in Table 2.7. Edquist and Jacobsson (1984) carried out a detailed analysis of the intensity of use of machine tools in various sectors in the US. The precise intensity of use (and therefore the impact on productivity and competitiveness) appears to be correlated with functions (with high use in products requiring milling, drilling, boring and turning), requirements for high quality and precision made parts (i.e. aerospace), and where a varied product mix demands flexibility.

In terms of the size of users, large firms are still the most intensive users of CNC machine tools but small and medium sized firms are begining to invest heavily as well. In Japan firms with less than 300 employees accounted for 29 per cent of domestic shipment in 1970 and 69 per cent in 1981. In the US 40 per cent of all CNC machine tools are now in plants with less than 100 employees and 63 per cent of tools installed in very small plants (less than 20 employees) are less than five years old (Watanabe, 1984).

TABLE 2.7

Distribution of Numerical Control Machine Tools by Sectors in Japan (1981) and the USA (1983)

	Japan*	%	USA*	%
General machinery	11,394	43	52,541	51
Electrical machinery	4,262	16	10,772	10
Transport equipment	6,276	23	15,284	15
Precision machinery	1,775	7	4,874	5
Metal products	1,460	5	14,463**	14
Casting/forging products	580	2	2,662***	3
Miscellaneous	978	4	2,102	2
Total	26,725	100	103,308	100

Source: adapted from Edquist and Jacobsson (1984)

* The Japanese inventory covers plants with 100 employees and more. The USA inventory covers all size classes.
** Fabricated metal products
*** Primary metals.

Along with the impact of numerical control technology, the single most important feature of the international machine tool market has been the swift rise to dominance of the Japanese. Again taking the lathe markets as an example, in terms of value, the Japanese share of world production rose from 15 per cent in 1975 to nearly 45 per cent in 1981; in terms of units produced, their share rose from 30 per cent in 1975 to 62 per cent in 1981. Due to a doubling in the Japanese export ratio (from 34 per cent in 1975 to 69 per cent in 1981), Japan's share of world export markets in lathes grew in unit terms from 13 per cent to 50 per cent and in value terms from 6 per cent to 35 per cent between 1975 and 1981 (Jacobsson, 1985).

The main reasons for Japan's phenomenal success in the international market for CNC machine tools and lathes in particular should be mentioned here since they have important implications for our later policy discussions. First, the major domestic users of machine tools such as the automobile industry undertook an intensive innovative effort to develop these tools for their own use. This was an important source of stimulus and feedback to the equipment manufacturer. Second, producers set out to capture scale economies in machine tool production based on the extensive use of automation technologies and via product standardization so that unit costs were considerably reduced - estimated at one half of those of US firms in 1981. Third, the Japanese identified particular market niches at the lower end of the cost/complexity scale and designed superior products to fill these niches. Fourth, the producers established an extensive worldwide network for marketing and after-sales service (either by themselves or via trading firms) which served to cultivate demand among users normally ignored by other firms. Today the Japanese machine tool industry has its own network covering more than 130 overseas locations in developed and developing countries. Finally, and most importantly, 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 per cent. Since the CNC unit accounted for a substantial share of total costs (25 per cent) this gave an important boost to their price competitiveness compared with conventional producers who manufacture machine tools in small batches.

The trends in technical change and market structure have important implications for developing countries, both in terms of the future possibilities for export of machine tools and other equipment, and in relation to the overall competitiveness of the domestic engineering industry. These implications are taken up in Chapter 3. Below we present some limited information on the use of machine tools in the Third World.

Some aspects of diffusion in developing countries

Demand for CNC machine tools in developing countries has begun to grow compared to that for conventional tools though it is largely still limited to Asian and Latin American NICs. In South Korea and Taiwan the share of CNC lathes in total lathe investment grew from 2.4 per cent and 7 per cent respectively in 1977/78, to 34 per cent and 20 per cent respectively in 1981/82 (Jacobsson, 1985). In Argentina though, NC tools accounted for only 6-9 per cent of capital goods imported between 1978-1982 and NC lathes accounted for 38 per cent of all imported lathes (Chudnovsky 1984). In Brazil, there were 834 NC machine tools in 1983 (compared with less than 400 in 1980), of which 422 were domestically produced (Stenmer and Ferreria, 1982). Production and demand for CNC tools in five NICs is given in Table 2.8. The numbers are still quite low compared to developed countries but the upward trend is significant.

Comparative information is not really available on users, but capital goods firms are undoubtedly the leaders. In Argentina the stock of machine tools (principally lathes but also milling and drilling machines and machinery centres) stood at 330 units in 1981. Large firms are the greatest users but small and medium sized firms are begining to invest in CNC tools. The range of products produced is fairly typical and includes turbines, pumps, valves, oil, nuclear and hydroelectric equipment, agricultural machinery, shipbuilding, defence equipment and automobile components (Chudnovsky, 1984). A similar pattern is likely to be found among the 200 users in Brazil (of which 113 used only one tool).

TABLE 2.8

Production and Demand for CNC Lathes in five NICs (in units)

Country	Production		Demand	
Argentina	10-15	(1981)	60- 65	(1981)
Brazil	36	(1980)	85	(1980)
India	4	(1981)	33	(1980)
Korea	222	(1982)	100-125	(1981)
Taiwan	174	(1981)	123	(1981)

Source: Jacobsson (1985)

Proliferation of Process Control in Industry

Microelectronics-based process controls are diffusing rapidly across the industrial sector. Process controllers can range from simple programmable controllers costing less than $1000 and introduced into single pieces of equiment, to plant level control systems using mainframe computers. One of the most important characteristics of microelectronics-based process control systems is that these systems allow 'real time' access to management and plant supervisors. 'Real-time' refers to the capacity of the system to provide instant access to all information relating to the production process - including data on capacity utilization, materials usage, process parameters, operators performance, downtime, cost overruns, deviation from production schedules, the location of goods in the chain of production, etc. This vastly improves the ability of management to oversee the production process, avoid bottlenecks, optimize product mix, etc.(see Bessant, 1982, for a discussion). For plant level control units, the core of the system is usually a powerful mini- or main-frame computer. It operates on the basis of data recording terminals distributed through all stages of production. Normally these would be linked to the machinery itself (and indeed equipment control systems can perform this process) as well as being placed in other strategic locations, i.e. supervisor stations, warehouse and distribution points, etc. The distributed computing and information processing power of mini- and micro-computers allows the bulk of the data collection, processing, instruction translation and transmission functions to be carried out at the machine location.

One indication of the demand for process control technology can be gleaned from the fact that the largest users of 16 bit and 32 bit microprocessors over the next four years (a market of nearly $1.5 billion) will be in the industrial process control area. A survey reported in Electronics Week indicates that US suppliers of intelligent devices such as programmable controllers are experiencing an annual growth in demand of 25-30 per cent (Electronics Week, July 1984). Applications are already too diverse to be surveyed in this text but Appendix III gives details on a selection of process control applications across sectors and countries.

To illustrate further the diversity of process control and microelectronics application and the way in which these are affecting industrial production, we consider in more detail developments in the clothing and textiles industry.

Technological pull in clothing and textiles

A common effect of the introduction of many innovations is that they require or stimulate changes to other parts of the production process in order to facilitate their efficient use. What might be described as a 'technological pull' effect is particularly strong where microelectronics is involved. In the clothing industry, with the high rates of continuous cutting which can now be achieved with CNC cutters, it becomes very important to ensure a continuous supply of piece goods of consistent quality that can be spread accurately and efficiently. Microelectronic controlled spreaders are under development which allow for the complete automation of the spreading function - threading, re-rolling, cutting and lap positioning. With these machines it will be possible to lay the cloth automatically, taking into consideration the nap and length for an unlimited number of layers.

A central feature of automated spreading is the need for an automatic fault detection system to be in place at the inspection stage. This would identify faults and, in effect, 'tell' the spreading unit their location. This is where developments in the textile industry come into play. Apart from the microelectronics applications in the area of computer-aided design of textiles, ink jet printing, improved yarn preparation, and the process control and monitoring of knitting and weaving machines, developments are also occurring in fault inspection which will facilitate automation in the clothing industry.

Ford Aerospace and Communications Corporation has developed a computer controller laser scanning fault inspection system for use by textile firms producing undyed and unfinished goods. The laser beam scans across the fabric surface at an average of 250 yards per minute, compared to the 50 yards per minute achieved with manual techniques (Halliburton, 1980). The computer can handle up to 99 different styles and is capable of recognising 12 categories of weaving imperfection. The accuracy rate of the six systems in use in the US is estimated at 90 per cent, which is nearly twice the detection rate estimated for current techniques.

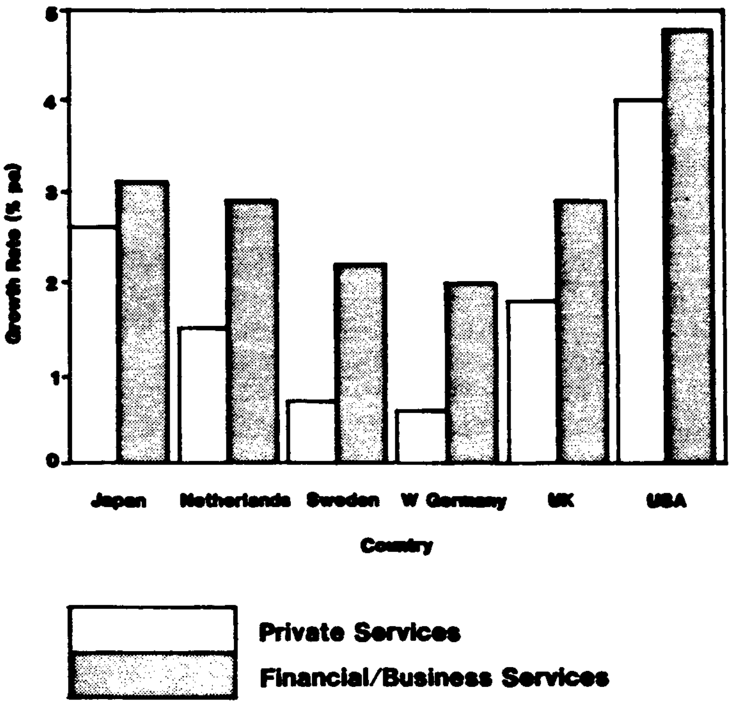
Related developments involve the dyeing process. In the late 1960s and early 1970s, both textile and electronics companies developed sophisticated sensors linked to computer control and monitoring of process parameters such as temperature, dye bath strength, etc. Previously the wide margins of error in the process of dyeing were concealed by lack of dye bath monitoring downstream, but with automation of that stage, existing techniques of dye mixing and colour adjusting were no longer adequate. Now, advances in colour physics combined with the information processing capabilities of microcomputers have led to the development of sophisticated computer-based spectro-photometers which allow the precise and repeatable specification of colour recipes to be prepared automatically and to an extremely high degree of tolerance. This allows optimisation of the dye bath and consistent colours in the fabric delivered to clothing manufacturers.

Another innovation developed for use within the clothing industry involves a microprocessor-based shading device, developed by firms such as IBM and Union Carbide, which precisely 'reads' the colour of incoming rolls of fabric and allows them to be correctly graded and sorted. This eliminates the need for visual shading and greatly increases the ability of the inspector in the clothing firm to shade and sort piece goods accurately. A microelectronics-based technological 'imperative' or 'pull' can be seen to be at work in each of these innovations. It occurs both in the need for these innovations to be developed in order to facilitate the use of automated cutting and CAD equipment in the clothing industry and in the central role that microelectronics technology itself plays in these innovations. It is interesting also to note that many of the innovations were developed by, or in conjunction with, firms from electronics related industries such as IBM, Ford Aerospace, Camsco and Instrumental Colour (set up by a former employee of General Electric of the US). Both of these trends are occurring elsewhere in the industrial sector and provide yet another indication of the heartland nature of microelectronics.

Service sector and office automation

The importance of the service sector and service activities hardly needs to be emphasized. At the purely functional level, office work, which is essentially concerned with information processing, pervades all areas of economic activity. A large part of this work is of an intra-firm and intra-institutional clerical nature, but particularly in specialised services, the activities involved resemble a production process dependent on the collection of information-intensive inputs and its transformation into information intensive output.

Figure 2.1: Employment Growth Rates in the OECD Service Sector,1970-1979



Source: Barras, 1984

UNCTAD (1983) calculated that in 1979 service activities in the developed economies accounted for 67 per cent of GDP and 51 per cent of GDP in the developing countries. Figure 2.1 gives a picture of the rise in the share of service-related employment in the OECD countries in the 1970s. The fastest growing service sectors are those concerned with finance and professional services. These have the highest concentration of office based employment and information occupations, are most directly affected by information technology and typically comprise between 30-40 per cent of all employment in OECD economies (Barras, 1984).

The emergence of microelectronics has led to the development of a large variety of devices for use with the office and other service sectors. These include the increasingly ubiquitous electronic word processers (stand alone and communicating) and electronic typewriters; automated teller machines; point of sale terminals and optical character recognition systems; an enormous variety of business computer systems; electronic mail and facsimile machines; viewdata and videotex systems; intelligent workstations; computer microfiche systems; and miscellaneous computer systems to handle virually every form of information collection, processing and transmission. On top of this one needs to consider the tremendous advances that are occurring in telecommunication and computer technology which allow for an endless variety of system configurations. For instance, one leading office automation equipment supplier in the US offers 135 different system configurations for use in intra- and inter-firm activities. Finally, the profusion of techniques for information processing has in turn created enormous opportunities for creating new services and new service industries.

Since many (but not all) service activities are by definition highly information-intensive, the range of applications of information technology and of office automation in particular is extremely broad. Appendix IV gives a selected list of the types of service sectors where applications have been developed. A good example of how individual companies are making use of information technology comes from Rada's (1983) description of the American Express Company's use of the technology. American Express has nine major information processing centres in the US and abroad, 70 large computer systems and 229 smaller installations. These support 17,000 on-line terminals within the company, 5,700 point of sale terminals and 50 direct links to approximately 30,000 terminals at airlines and department stores.

Investment levels and future trends

In the 1970s the service sector increased its investment in capital stock at a higher rate than the manufacturing sector as a whole, albeit starting from a much lower base level. The UK is a good example: between 1973 and 1981 the annual rate of increase in plant and machinery was 10.6 per cent, compared to 5.8 per cent in all fixed assets. This trend represented a shift in the pattern of investment in the sector away from high value buildings and offices which contribute only indirectly to output and productivity growth (Barras, 1984). It is difficult to separate out the share of this investment accounted for by information technology but the sector does account for a large share of computer investments. In the UK, the total installed value of all general purpose hardware is estimated to have grown from £3.1 billion in 1978 to £5.7 billion in 1981 and two thirds of this is in service industries (BIS-Pedder 1984). In the OECD, investment in computers and peripherals grew annually at 15-20 per cent during the 1970s and the share of the service sector is probably equivalent to or even higher than in the UK case.

As with the speculation surrounding the imminent arrival of the factory of the future, there has been a profusion of over-ambitious forecasts about the advent of the paperless office. This is still far from being a reality, but the demand for office automation is growing rapidly. Excluding computers, the world market for office automation products was estimated at $5 billion in 1982 and was forecast to continue to grow at a rate in excess of 15 per cent a year (Bessant 1983). This is probably a conservative figure. For individual components like word processors, the US market stood at $2 billion as far back as 1980 - an increase of 56 per cent from 1979 (Wernecke, 1983). Despite the high rates of investment in new office automation products, reprographics still dominate, but their share of the total investment is expected to fall to 20 per cent by 1990, with the bulk of the rest made up by investments in text generation and transmission equipment.

In banking automation the installation of automated teller machines (ATMs) (estimated market of $4 billion in 1982) has grown rapidly, as shown by Table 2.9. The five London clearing banks trebled their investment in information technology between 1975 (£257 million) and 1981 (£749 million) - an annual growth rate of 19.5 per cent. This in turn spurred a 35 per cent annual increase in ATMS. (Barras 1984). US, West European and Japanese banks have been investing at similar or even greater levels and have attained an estimated annual improvement in labour productivity of 4.5 - 5.0 per cent.

TABLE 2.9

Distribution of Automated Telling Machines in the US, Europe and Japan (in units)

Country	1975	1977	1981	1995
USA		6,300	25,400	90,000 (estimate)
Europe	3,800		11,000	
Japan			27,000	

Source: Bessant (1983)

Investment levels by the private financial sector are also high for the creation of international communication networks. The West European banks spent over $1 billion developing and introducing a network called SWIFT, which connects over 700 banks in 26 countries and handles an average of 50,000 transmissions every day. Citibank of New York spends $40 million a year on its international telecommunications network which connects branches in more than 100 countries and handles more than 100,000 transmissions per month; while American Express spends between $300 and $400 million developing, operating and maintaining the information network described above (Rada, 1983).

The points made earlier about the trend towards systems integration apply par excellence to the use of office automation and information technology in the service sector. Both the qualitative and the quantitative gains arising from system automation are substantial and hence there is a relentless drive towards increased integration within the service sector. We earlier mentioned the case of the electronic cash register. In retailing, first generation point of sale terminals are now found in virtually every retail outlet, large or small, in most OECD countries. A major push is now on to introduce bar code reading at sale points (over 70 per cent of all products are bar-coded in Europe while in the US the figure is close to 100 per cent) linked with automatic inventory control and stock ordering services to centralised warehouses. In the UK by 1985 about 1000 multi-outlet retail firms will have these integrated systems in place (Bessant, 1983). The typical office is still largely characterized by the use of stand-alone pieces of equipment, particularly word processors. However, where information is the principal product of the firm, information technology-based linkages made within and between institutions, both nationally and internationally, are already being implemented.

As noted above, developments are furthest advanced in the financial sector where major financial institutions are linked to facilitate inter-bank transactions at the national level. Apart from inter-bank link ups, corporate customers will soon be tied directly into the banking network, as will private customers who will be linked via electronic funds transfer systems to the retail network.

Future trends will build on the rapidly increasing base of self-contained data and text-processing equipment. Within firms these units will be linked into local area networks (LANs) and augmented by multifunction workstation terminals covering text, data, voice and picture transmission. Barras (1984) graphically described the implications of these developments in the financial world:

> "In the longer term, say five to fifteen years, the most radical transformation of service activities could occur through the development of national and international broadband viewdata networks offering interactive services to both business and domestic premises. There seems likely to be a huge potential market for the home provision of services such as shopping, banking, electronic mail, entertainment and education, once the right infrastructure is installed. The growth of broad-band networks would therefore provide the catalyst for the development of totally new forms of service provision in both the private and public sector and would transform the technical, market, and even legal environment in which financial and consumers service firms must operate." (Barras, 1984, p.23-24.)

The above discussions barely convey the scale and complexity of developments in the service sector, nor the rate at which change is occurring. We are still at the earliest stages in relation to these developments. It is almost certain that the glowing forecasts currently being made about the pace of office automation or indeed the range of service tasks likely to be automated will prove over optimistic - perhaps by a considerable degree. However, there can be little doubt that profound changes will occur and the implications are extremely important, not only for the domestic service sector but also for the international flows of services which are discussed in Chapter 3.

Section 3: Future Trends in Automation

Our discussion so far has concentrated on the use of automation technologies in "stand-alone" installations typical of the current period. Equipment suppliers and user firms will for some time yet be preoccupied with further developing and introducing automation technologies in this form. However, as we noted in our introduction to this chapter the inherent logic underlying the industrial exploitation of microelectronics is towards achieving systems integration between what are presently isolated "islands of automation". Systems level integration is possible because automation technologies share a common language of control based on the binary logic system used by the microprocessor and by computers. By using a common way of processing and transmitting information and common data bases, individual systems can in theory and in practice be linked together and their operations integrated to allow fully automated production to occur. In effect, this would involve not only the automation of the manufacturing sphere but the integration of manufacturing with design under the co-ordination of management. In the literature this ultimate merging of the design, manufacturing and management function is termed the "factory of the future" and is described in glowing terms in the following quotation:

> "The factory of the future would use interactive graphics (CAD) for design and planning, with final design transferred to NC controls on machine tools on the shop floor. Time shared computers would link work stations, stock rooms, marketing and transportation functions. On the factory

> floor, programmable controls would be linked with lasers and robotics with which solid state inspection cameras linked to computers would carry out quality control." (Pierce, 1981,p.10)

Though the imagery is quite dramatic, the reality is somewhat different. Factories of the future do indeed exist but still in relatively few numbers. The future is not yet here and even when it does arrive the totally unmanned factory will probably be the exception rather than the rule. Nevertheless the broad thrust of industrial innovation process within the developed countries has clearly shifted towards the design and introduction of integrated manufacturing processes. Before detailing future trends in this area we briefly discuss the conceptual process of automation to allow us to put into context both the evidence presented in Section 2 and the analysis in Section 4.

There is in this field a tendency to be preoccupied with the current avalanche of anecdotal evidence concerning automation and to miss the broad underlying trends. While this is understandable it raises difficulties for the purposes of policy analysis. This is particularly true if the analysis is pursued from a Third World perspective, since countries in the early stages of industrial development need to make long term choices about the nature of that process. In a world where change is evolutionary and proceeding slowly, past and current patterns are a reasonable guide to the future. But under conditions of rapid and fundamental change in the laws of production, a long term perspective is essential lest the wrong path is chosen.

In a recent set of publications, Kaplinsky (1984 and 1985) has developed a model of the stages of firm-level automation which is particularly useful for our purposes. He departs from the conventional treatment of the topic by Bell, Bright and others, where the focus is on automation of the production process only. Kaplinsky argues that to understand the full impact of automation on the firm, one needs to start by recognizing that the activities of the modern firms can be separated out into three spheres - one incorporating the process of design and engineering; another involving the process of manufacture where physical inputs are transformed into a specified output; and a third incorporating all managerial functions in the sphere of co-ordination. Within each sphere, a set of discrete activities are carried out - drawing, copying, engineering etc. in the design sphere; handling, forming, assembling, storage, etc. in the manufacturing sphere; and similarly a range of managerial tasks in the co-ordination sphere. Each of the activities may be carried out by separate individuals with different skills and often using different pieces of equipment. Prior to microelectronics and indeed beginning with the Industrial Revolution, each of these activities experienced a degree of automation which involved the substitution of capital for labour. However the distinguishing feature of this period is that usually the automation only affected separate activities carried out within the individual sphere of production. Rarely were discrete activities within spheres linked together via automation. The major exceptions were to be found in the case of continuous process industries, or mass production industries relying on the assembly line, where the degree of integrated automation was already quite advanced by the early 1970s.

The emergence of microelectronics and the development of automation based on this technology has pushed this process onto a new plane where automation is now occurring with different degrees of intensity and rapidity at three levels:

The first level is intra-activity automation which relates to the automation of individual activities. This is the type of automation we were primarily discussing in Section 2 - the use of CAD for draughting in the design sphere; the introduction of CNC systems to machine tools and other equipment in manufacturing; and the use of word processors in the office. The key feature of this type of automation is that it is limited to an individual activity and is isolated from other activities in the same or other two spheres of production.

The second level is intra-sphere automation where the key feature is the integration of individual activities within the same sphere - but still isolated from other spheres. For instance CAD systems are used for draughting, detailed design and tool path specification; "machining centres" are used in manufacturing to perform several different tasks, etc.

The third level is inter-sphere automation in which activities in separate spheres become integrated together via their common dependence on digital control systems - the factory of the future described in the above quotation from Pierce.

The significance of these developments is captured in the following quote:

> "What is at issue now is the transition to the automated enterprise. Whereas the last three centuries have seen the gradual evolution and specialisation of the three spheres of production beginning in small factories and then writ large through global production via TNCs, what we are now beginning to witness is the re-emergence of the unitary, undifferentiated firm. The development of the automated enterprise, embodying the extension of inter-sphere automation throughout the firm, is leading once again to the unity of spheres ... It is in this transition to the integrated enterprise and the enormous systems gains in efficiency that are now possible where the historical significance of microelectronics technology is to be found." (Kaplinsky, 1985, p.72-73.)

Section 4: Evolution of Automation within the Firm and the Emergence of "Systemfacture"

This section presents evidence on trends in intra-sphere and inter-sphere automation as well as briefly discussing newly emerging trends linking input suppliers and final product manufacturers.

Intra-sphere automation in manufacturing

Within the manufacturing sphere the development of NC technology has already greatly improved and simplified the control, programming and operation of machine tools which lie at the heart of many engineering production processes. It has also facilitated the development of one of the automation technologies we have not yet discussed - industrial robots. There is a great deal of debate about robots and their impact on automation - indeed the level of interest is such that "there are probably more published articles and interviews on the subject each year than there are robots sold" (Ayres and Miller, 1984, p.1). Most of these robots (about 30,000) have been used to perform tasks which humans are ill-advised to be doing anyway, such as paintspraying. Their employment impacts so far have been limited (in the US there is one robot for every 1000 workers in manufacturing industries) and the economy-wide effects are impossible to discern. We believe the present concern over the impact of robots is premature in so far as the evidence does not yet reveal a major degree of labour displacement (see Edquist and Jacobsson, 1984). In this regard the real problems lie ahead when robots begin to be linked with machine tools (and other equipment) and transfer lines in integrated manufacturing systems characteristic of intra-sphere automation.

Much effort is now being directed towards the common co-ordination of robots and NC machine tools and the control of materials movement from one stage to the next. The development of high performance general purpose control systems described earlier has been the factor allowing the movement toward more flexible forms of manufacturing. All the advances discussed below essentially depend on the further improvement and refinement of these control systems and on developing the extremely complex software needed to facilitate their integration.

Three different forms of co-ordination and integration are being attempted. The first is direct numerical control, where the operations of a number of NC tools are controlled via a hierarchy of computers. Depending on the configuration, micro-computers attached to individual machines are linked to a mini-computer, and a number of mini-computers are linked to a mainframe computer. In this system, there is a two way flow of information. The micro-computer in the machine tool receives these instructions and translates them into operational parameters which can control the functioning of the machine, the use of tools, etc. Programmes for every part produced by the firm are registered and stored in the mainframe and when necessary these instructions can be transmitted to the individual machine tools via the mini-computer. The status, volume and quality of production for each tool can be transmitted back to the mainframe giving managers an instant overall picture of the production process.

Direct numerical control is a reasonably well-developed system of integration - examples of the direct control of up to 100 machine tools have been identified (Gunn, 1982). Typical of these is a DNC system at Normalair Garrett in the U.K. which has been installed to produce complex one-off sets precisely machined components for the Tornado aircraft. It includes two machining centres and several machine tools connected by a pallet transfer system. Inventory savings alone are considered sufficient to pay off the £1 million investment cost, (Senker, 1983).

At the second and third levels, the CNC tools are linked not only electronically but also by some form of materials handling system. In the manufacturing cell, usually two or three CNC tools are grouped together to perform a related sequence of machining or assembly operations on a work piece. A stand alone robot 'services' the cell by loading and unloading the work pieces into each tool and transferring them between tools until the prescribed sequence of operations has been performed. For example, in the UK the 600 Group has installed an advanced manufacturing cell costing £3 million which consists of nine machines in an automated turning cell designed to produce components for a new lathe.

A further stage in integration involves linking a number of NC tools or manufacturing cells together via an automated transfer line, again controlled by a computer hierarchy. Arrangements of this sort have come to be called flexible manufacturing systems. As shown in Table 2.10 these systems extend the range of manufacturing tasks that can be automated, thereby greatly increasing the flexibility of the production process while at the same time facilitating a high level of capacity utilisation.

The degree of automation can be further extended by tying advanced manufacturing systems into an automated parts storage and retrieval system. There are few examples of this degree of automation in use but they do provide a glimpse of the level of integration which the technology makes possible. British Leyland's Land Rover factory, for example, has such a system in operation for engine assembly. Bought-in components are coded and automatically stored. When required for production, pallets containing the component and some 300 engine trolleys (which carry the gradually assembled engines) move through the factory, via a 1,500 metre overhead monorail system, from work station to work station, where some automated assembly and robot welding is carried out. Some 1,200 signal points on the factory floor permit monitoring at all stages of production including work stations and allow continuous feedback on production status (Connors and Garner, 1981).

Kaplinsky (1984) and Gunn (1982) give other examples of flexible manufacturing systems and other types of automation currently operating within the manufacturing sphere which demonstrate the diverse ways in which automation building blocks are already being combined together.

TABLE 2.10

Comparison of Manual Manufacturing Steps Eliminated by Various Degrees of Computer Control

Step	Production methods Conventional	 Stand alone NC	 Machining centre	Flexible machining centre
1. Move workpiece to machine	M	M	M	C
2. Load and affix workpiece on machine	M	M	M	C
3. Select and insert tool	M	M	C	C
4. Establish and set speeds	M	C	C	C
5. Control cutting	M	C	C	C
6. Sequence tools and motions	M	M	C	C
7. Unload part from machine	M	M	M	C

Source: Ayers and Miller (1983)

M = Manual
C = Computer control

As flexible manufacturing systems mature, they are likely to affect both ends of the production spectrum, leading to opposite sets of effects. In mass production, economies of scale will be lowered due to the ability to re-adjust machinery more rapidly. Consider, as an example, the assembly of motor cars. With existng technology, unit costs are minimised when annual production exceeds 500,000 cars of a single type. However, the new Mazda assembly plant in Japan is built for flexibility. It will almost instantaneously re-adjust and assemble in quick succession the 323 front-engined, front-wheel drive small hatchback car, the 626 front-engined, rear-wheel drive middle-sized saloon and the RX7 rotary-engined sports car. Thus whereas three separate assembly lines, each producing half-a-million cars a year, would have been required in the past to minimise unit costs, now a single assembly line will produce all three cars, in any combination of numbers, with similar costs of production (Kaplinsky, 1984).

In batch production, the opposite effect will be evident. The flexible machinery is significantly more expensive, but output will be higher; hence it introduces economies of scale for the first time into small batch production. Consider the following characteristics of US industry. In the engineering sector as a whole one estimate is that metal cutting machines work for 12 per cent of available time, metal forming equipment for 15 per cent and welding equipment for 22 per cent. In small- and medium-batch workshops productive cutting time is as low as 6 per cent. Much of this lost time is due to changeover costs and single shift utilisation, but by introducing automated flexible manufacturing systems, much of this time can be recovered, allowing significant improvements in both capital and labour productivity (Ayres and Miller, 1983).

Diffusion and dispersion

Information is very scarce on the rates of diffusion of these more advanced forms of manufacturing system but what is available suggests that diffusion even of the least complex types of system is still limited. Edquist and Jacobsson (1984) offer the most comprehensive overview and they point out that Japanese and Swedish producers of CNC machine tools estimated that in 1983 only 10 percent of their tools were equipped with programmable materials handling devices. For manufacturing cells involving the use of robots, numbers are similarly low. No more than 10 per cent of the robots installed in West Germany and the UK served machine tools. Sweden is estimated to have a higher percentage but is still below 25 per cent. No doubt these numbers are increasing but they remain low compared to earlier expectations.

More information is available on flexible manufacturing systems (FMS) and this too shows the limited spread of the technology so far. In the OECD countries there are approximately 150 FMS installed which incorporate approximately 1200 CNC machine tools. This is not an inconsiderable number but compared to the 130,000 tools installed in the US and Germany alone in 1982, FMS is clearly in the very early stages of diffusion. A good idea of the dispersion of FMS across sectors is given by Table 2.11. which shows the range of final products incorporating parts produced by these systems.

The limited diffusion of FMS can be interpreted in different ways. One way would be to suggest that diffusion is limited now and will remain so in the future because of the considerable costs (anywhere between $5 and $200 million) and technical difficulties involved (engineering/design very often runs into several hundreds of thousands of man hours) in making the systems operational and cost-effective. These obstacles are undoubtedly considerable - but to argue that they will not be overcome in time, significantly underestimates both the amount of effort currently going into the development of FMS technologies and the compelling force of the substantial financial returns which accrue to successful innovators.

These gains are reviewed in the next chapter. Here we only wish to point out that in a recent authoritative review, Ayres and Miller (1984) argue strongly that FMS will be introduced in much greater numbers in the near future, particularly as related developments in visual pattern recognition, force sensing and artificial intelligence begin to mature. They identify a number of systems, both installed and under development in a wide range of applications outside of those in current use - in sheet metal fabrication, wire harness assembly, open die forging, electronics and computer assembly, and assembly of display-writers.

This author's research has identified a very considerable R&D effort now being directed towards the development of FMS in the clothing industry - a sector which even the most optimistic observers believe will defy the automation process. Public and private sector enterprises in the EEC, Japan, Sweden and the US are collectively investing nearly $150 million in R&D in this area - with the Japanese expecting to have a cost-effective system available by the early 1990s. If FMS technology is even beginning to emerge in traditionally technologically stagnant sectors like clothing, there seem few sectors that are not likely to be affected in some way.

TABLE 2.11

Final Products Incorporating Parts Manufactured by Flexible Manufacturing Systems

Final Product	Number FMS	Percent
Automobiles and trucks	27	21
Machine Tools	22	17
Tractors and construction machinery	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 equipment	4	3
Office machinery	4	3
Optical instruments	3	2
Ship engines	2	2
Material handling equipment	2	2
Others	13	10
Total	129	100

Source: adapted from Edquist and Jacobsson (1984)

Inter-sphere automation

Under the category of inter-sphere automation, there are far fewer examples of efforts to achieve systems integration on the scale envisaged by disciples of the 'factory of the future'. General Electric of the US has sought to become a global leader in this area of technology. To do this it has embarked on a $700 million acquisition programme to take over a variety of high technology firms in the CAD, robotics and numerical control fields. It has also initiated a $2 billion programme to re-equip its own manufacturing plants, including $316 million towards building a new fully automated plant for the manufacture of locomotives. This latter has been described as follows:

> "Starting at the beginning, the design output of the engineering department will be passed on to the manufacturing engineers in electronic form, rather than as drawings, and will then move through materials control, which will automatically schedule and order materials and keep track of stock and production. All this information will come together in the factory in the host computer, which will contain in its memory details about how, when and what to produce. This in turn will send instructions to the computer-controlled equipment, such as numerically controlled machines and robots, which will actually do the job. Quality controls, financial data, and customer service records will also be plugged into the same system". (Lambert, 1983.)

There are a few other examples of this kind, but for the part most inter-sphere automation projects as yet involve a more limited degree of integration. Progress is farthest advanced in linking CAD systems to CNC machine tools. With both NC and conventional machine tools, the operator would set up his machine based on engineering specifications provided by the designer. The information needed by the designer to specify the geometry of a part is the same information needed by the machinist to determine the operation of a machine tool. With CAD, parts programmes can be fed directly into the machine tool without human intervention. Large manufacturers, particularly those involved in automobiles, aerospace, heat exchangers, farm machinery and machine tools, are using and experimenting with CAD/CAM linkages of this type, and the number of installations will rise gradually as experience is gained by users and as systems producers move from custom to standardized designs.

One of the more surprising examples of widespread diffusion of CAD/CAM comes again from the clothing industry. Following rapidly after the development of CAD applications in the sector in the mid-1970s, a CNC cutting system was developed by an American firm. The cutter must be used with the CAD system and despite the high cost of a combined installation, of up to $1 million, more than 300 cutters have been sold. This probably represents one of the largest concentrations of inter-sphere automation in the whole of the manufacturing sector.

One of the key obstacles still impeding the more rapid diffusion of CAD/CAM technology has been the high costs and time consuming efforts required to develop software and interface solutions. The scale of these problems had not been foreseen earlier either by observers or by those involved in the plants (Bessant, 1982). However, there are a number of initiatives underway to provide primarily software solutions to these difficuties; they combine information produced at the design stage with that from the manufacturing sphere.

One such method is called Group Technology which allows a firm to rationalise the identification, storage and retrieval of parts used and produced in its factory. As Gunn (1982) describes it, Group Technology is essentially an 'electronic card filing system' which lists every part used and sorts them according to physical characteristics and related manufacturing information such as tools used, set up times, etc. Production can then be planned (using a CAD system) in order to optimise the progress of the part through successive manufacturing stages. Labour savings and time efficiencies are considerable. Gunn (1982, p.97) reports that "in many companies only 20 per cent of the parts initially thought to require new designs actually need them; of the remaining new parts, 40 per cent could be built from existing designs and the other 40 per cent could be created by modifying an existing design". Another computer based technique which has been developed to reduce production time and eliminate most inventory-related costs is called Manufacturing Resource Planning. This technique extrapolates backward from final delivery date to scheduled labour use and machine time, as well as the ordering of bought-in parts and materials.

The degree of information required to develop these types of system has proved to be a stumbling block for some firms. Nevertheless, in the US alone over 100 systems of the above two types have been developed and are currently in use at more than 10,000 plants. They have proved particularly valuable for units producing many products in small quantities, where maintaining a large inventory reduces profits. In a survey of the systems in use, Gunn (1982) reports inventory reductions of up to 33 per cent accompanied by other equally significant reductions in parts costs and improvements in throughput rates.

"Just in Time" Manufacturing: Emergence of systemfacture and inter-firm restructuring

We have seen how the organisation of production within individual firms is being affected by the diffusion of automation technology. In some sectors, similar fundamental changes are occurring at the level of inter-firm relationships. These developments involve a combination of automation related changes and organizational innovation. They are best illustrated in relation to the automobile industry where since 1970 Japanese producers have pursued their ultimate goal of developing a continuous flow production process from the steel foundry to customer delivery without reliance on buffers or inventory and with outside component supply fully integrated into production. This approach has come to be known as the Kanban or 'Just-in-Time' system and it has completely revolutionised the mode of automobile production and firm organization which, starting with Henry Ford's assembly line, evolved over the last 50 years.

The essential features of the system are as follows. The production of cars is based on the zero inventory principal, which means no buffer stocks are held at the plant. This necessitates frequent component delivery (up to 2-3 times per day) and absolutely minimum stocks. Japanese auto firms report they have enough components in their inventories to support production for only 30 minutes. Associated with zero inventory is a "zero defects" policy which is strictly imposed on component suppliers. Continuous production must be maintained to achieve scale economies, and with no inventory buffer there is absolutely no room for sub-quality components.

Finally, maximum advantage is taken of FMS at all stages of assembly and in-house component production. This means that though scale economies are reduced, the possible range of product mixes is increased, and down times are reduced to a minimum. For example, Toyota is able to change product lines at least once a day compared to US firms which can only change lines at intervals of 10 days or more.

This revolution in production and organisational technology has two implications we wish to point out here. First, relationships between component suppliers and final product manufacturers are being substantially altered. To maintain continuous component supply, suppliers have to be located in close proximity to the point of final assembly. For instance, General Motors requires that most of its component suppliers to be located within 100 miles of its new assembly plant in Michigan. The number of components, and hence component suppliers, is also reduced - in the case of GM and Volvo by between 40 and 50 per cent. Overall the share of components imported from low wage suppliers overseas is expected to drop dramatically - from 40 to 10 per cent in the case of British Leyland. Component suppliers themselves have to adopt FMS technologies and stringent quality control. Following the recent wave of re-equipment among major automobile manufacturers (responding to the Japanese), major component manufacturers are having similarly to undertake massive new investments in FMS technologies. Finally, 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.

The completely new standards of organisational efficiency and automated production being pioneered by the Japanese have had a devastating effect on their competitors. Japanese firms have been able to reduce the amount of time required to build a car from 250 hours to nearly 120 hours. Consequently they are able to ship small cars to the US, duty and transport paid, for 30-40 per cent less than the Americans can manufacture them. Even the most advanced of developing country manufacturers cannot compete with this performance. The South Korean company, Hyundai, with a $1.00/hour wage rate were in 1980, was able to produce its car (known as the Pony) for approximately $4,000 while the Japanese firm of Toyota, paying an average $7.00/hour wage rate, could build virtually the identical product, a Corolla, for $2300 (Jones and Womack, 1985). The 'Just-in-Time' approach to assembly is so far confined primarily to automobile assembly and computer manufacture. Even so, these two sectors are important for the Third World and the changes described above have some disturbing implications for policy, both for final product manufacturers and for component suppliers hoping to expand their international market share by relying on lower unit wage costs as a source of competitive advantage.

How likely is it that this approach to production organization will be of use to other assembly-based activities? It is impossible to guess at the moment, though the anecdotal evidence from the trade journals suggests that the ideas are being seriously explored in other sectors - such as clothing, consumer durable and machine tool producers.

The discussion in this section has attempted to illustrate the most important future trends in the industrial application of microelectronics. The capacity and flexibility of the microprocessor facilitates the integration of various levels of information manipulation and transmission which had previously required discrete steps in the production process. Frequently, these steps involve entirely separate technical systems, machines and operators, as well as different firms. However, as we have tried to show, the potential now exists for these activities to be carried out much more quickly and cost-effectively as part of a continuous process that has been redesigned and reorganized to optimise an entirely new set of parameters, of which the efficient flow of information is the most important. The key factor in this process is the increasing information intensity of production and the availability of compatible automation technologies. This is leading to a shift in emphasis in the process of technical change and in production organization, from improving the operation of machines to optimizing information flows within the manufacturing process as a whole.

Historically, the division of labour in manufacturing has increased the efficiency with which individual functions are performed, by reducing the overall time required to produce a final product. In much the same way, the use of microelectronics allows these steps to be totally integrated within a continuous process and reduces the time in production well below that achieved previously. The inherent logic which underlies this process of increasing degrees of specialization and integration is very strong both in technical terms and in relation to the pressures for cost reduction in a competitive global economy The advent of microelectronics sweeps away earlier obstacles to automation which were rooted in the use of analogue-based media to collect, manipulate and transmit information from one stage to another. In that case this process took place at the limit defined effectively by the speed of sound. This has now been replaced by a technology with the capacity to perform the same function at a rate akin to the speed of light. The effects of this quantum jump on the process of production have scarcely begun to be realized.

CHAPTER 3

IMPACTS AND IMPLICATIONS OF MICROELECTRONICS FOR TRADE, PRODUCTION, EMPLOYMENT AND DEVELOPMENT

Much of the debate within the developed economies surrounding the microelectronics revolution has been primarily focussed on its economic impacts. Owners of capital must weigh up the contribution that the introduction of MRIs will have on profitability and competitiveness at the level of the firm compared to the investment or R&D costs associated with bringing the technology into use. The labour force, while obviously anxious to see employers remain competitive, are worried about the effect of the technology on jobs as a first priority and on its implications for skill and the work environment. Governments, though concerned about possible short-run employment displacement effects, nevertheless take a longer perspective which views the adoption of the new technology as a means of ensuring long term growth and international competitiveness. Hence government policy throughout the OECD is oriented toward measures to speed the process of diffusion so that the period of 'adjustment' is minimised. The dilemma with which governments, employers and workers are confronted is that while jobs may be lost as a result of the diffusion of microelectronics, many more will go if the technology is not adopted.

While the economic impacts of information technology are obviously critical, the social implications of the technology are arguably the most important, since it is entirely possible that only those who become computer "literate" will eventually be able to benefit from it. This situation could only result in severe divisions and disruptions within the fabric of society. Thus even though less widely debated, the social changes likely to accompany the information revolution in the industrial countries will ultimately force their way into the consciousness of policy makers. Taken together, the economic and social implications of microelectronics obviously pose a whole range of policy problems for the major economic actors in the developed countries and for society as a whole.

When it comes to considering the impacts of microelectronics in developing countries, the issues need to be considered from a rather different perspective. This stems from the irrefutable fact that one of the fundamental sources of weakness and vulnerability in most developing countries lies in their failure to create a broad based capability to effect technical change - a failure which robs the economy of one of its most important sources of stimulus. In this context, the central technical policy issues in the short run are much less those of how to manage the consequences of technological change and much more those of how to get the process started in the first place.

This means that our view about the relative importance of the various economic and social implications of microelectronics differs from that of analysts concerned only with conditions in the developed countries. For instance where much of their concern is justifiably focussed on the employment and work related effects of microelectronics, we believe that in the short run these issues are much less important for the large majority of developing countries. Obviously employment effects of technical change do matter in a Third World context. Most of these countries suffer much higher rates of underemployment than the North but few of them have a social security system which can alleviate the hardships of the unemployed. In these situations the loss of a job can mean extreme suffering and hardship. However, the available evidence suggests that except for a few sectors in a few countries, the prospects for a high rate of diffusion of MRIs leading to widespread employment displacement are extremely limited. The major employment effects of the new technology for the Third World are more likely to come from the loss of international competitiveness (and hence market share) to efficient users in the North.

Indeed one could argue that the growth of the electronics industry world-wide has already created many more jobs in offshore assembly industries and the like than will be displaced elsewhere for some time to come. The automation of production in the electronics industry could lead to a relocation of offshore assembly activities within the developed economies. If this occurs it would have a quantitatively greater effect on job losses than any other use of the technology in the Third World. By the same token, the working conditons of the largely female labour force in the sector undoubtedly leave a great deal to be desired and should be improved wherever possible. But it is one of the great tragedies of the Third World that any job, no matter how unpleasant, is infintely preferable to the prospect of struggling for survival without work.

It is for these reasons that we have organised the presentation of material in this chapter in a way that allows us to highlight some of the most important implications of the technology as they specifically relate to the Third World - though once again we shall be drawing heavily on the experiences of the developed economies. We start in Section 2 with an examination of international trade issues as these relate to the competitive advantage of developing country exporters of manufactures. These issues are important because of the central role now accorded by many countries and international development institutions to the pursuit of export-oriented growth. Technologically induced changes in the determinants of comparative advantage could pose a threat or open up new opportunities to developing countries. These developments will have important implications for foreign exchange earnings, and therefore for the pace of industrial expansion and for the level of employment. In Section 3, we examine the evidence concerning the economic effects of the introduction of MRIs within the manufacturing sector. We focus largely on the implications at the level of the firm and try to highlight those areas where gains from the technology relate to its possible use within Third World firms. In Section 4, we examine more briefly the implications for work and employment in the developed countries' non-factor services. Finally in Section 5 we present some ideas on the broad significance of the microelectronics revolution for development strategies in the Third World.

Section 2: Shifting Patterns of International Trade and Comparative Advantage

To provide the proper context for this discussion we want to draw attention to two sets of issues. The first is the existence of a relationship between a country's capacity to innovate and its ability to capture and maintain an international market share. The second is the pattern of growth of manufactured exports from the Third World in the period since World War II and its effect on development strategies.

Changing context of competition within OECD

There are many theories which seek to explain the sources of international competitiveness among the industrialised countries. One that has gained increasing credence in recent years emphasises the importance of innovative effort within the domestic economy. Recent research has established a strong positive correlation between two factors. Using patents registered in the US by other countries as proxies for the level of innovative activities within those countries, Soete (1980), and Pavitt and Soete (1981), have shown that there is a long term, direct relationship between a country's patent share (in the US) and its world market share for manufactured exports. In a more rigorous test, exports per head in 40 industries for all OECD countries (except Iceland, New Zealand and the US) were regressed against patents registered in the US between 1963 and 1976. The results show a strong degree of correlation for capital goods industries experiencing high rates of technical change, and less significant results for consumer and intermediate goods where technical change is less dynamic and based on diffusion of innovations originating in the capital goods sector. Studies of particular sectors, particularly in the machinery group, show conclusively that non-price factors such as product quality are often central to trade performance (Rothwell, 1981).

Another body of literature which underlines this argument are the "technology gap" explanations offered by a series of studies carried out in the 1960s (OECD, 1970). These show that the technology factor is an important part of the explanation of the high rates of productivity improvement and economic growth that occurred in Europe and Japan in the 1950s and 1960s. In these arguments, the existence of a technology gap between Europe/Japan and the US in the early 1950s, spurred governments and firms in the former to embark on a sustained effort to close the gap for fear of their domestic industries being swamped by US technological strength built up during World War II. (Maddison, 1979). Sizeable investments in R&D and in the importation of technology (with extensive public sector support) succeeded in improving productivity to such an extent that in many sectors the "gap" was narrowed considerably or even disappeared by the late 1960s (except in sectors such as electronics which in the US received considerable public support during this period). As the gap closed, rates of productivity growth slowed as most of the countries approached the technological frontier achieved by leading US firms (Gomulka, 1971; Cornwall, 1977; Pavitt and Soete, 1981).(1)

At this point, several other developments began to impinge upon the established pattern of international competition among the OECD countries. First, the general slowdown in overall rates of growth served to heighten the degree of competition among international firms trying to maintain (or increase) their share of a more slowly growing market. Second, convergence in the levels of technological sophistication attained by these countries meant that there were more countries (and therefore more firms) capable of entering the market. Finally, pressure began to be perceived, if not really exerted, from NIC exports of labour-intensive manufactures at the bottom end of the scale of technological sophistication.

The combined effect of these developments has been to foster conditions of more intense technological competition among firms in OECD countries than had existed before (Soete, 1981b). This phase of international competition is expected to continue, at least throughout the 1980s. It has four important characteristics. First, declining or stagnant domestic markets have forced many firms to aggressively seek to expand their international market share. Second, technological factors, such as improved quality and the pursuit of cost-reducing technical change, will continue to be a crucial source of competitiveness - a process which is of course being greatly enhanced by the diffusion of microelectronics to user industries (OECD, 1980). Thirdly, heightened international competitiveness may lead to a less oligopolistic technology market, thereby increasing the opportunities for countries further away from the technological frontier to gain access to best-practice technology (Soete, 1985). Finally, it is probably correct to say that the experience of the 1960s and 1970s firmly rooted the notion that national policies for technology may be important for international trade competitiveness. The single most important factor behind this growing interest in innovation policy was the very strong export performance by the Japanese in the 1960s and 1970s. It became increasingly obvious that the Japanese success was no longer solely associated with low wages but rested much more on organisational and technological factors. The fact that the Japanese had a long-standing and active technology policy, both in relation to imports and for the development of indigenous technology, was not lost on other governments (Freeman, 1983). All four of these characteristics are important indicators of the changed nature of the international competitive environment that will be faced by Third World exporters in the last half of the 1980s. Those countries wishing to compete successfully in international markets in the future will be forced by these conditions to pay careful attention to technological issues and their links with economic policy.

Emergence of the Third World as exporters of manufactures

At the same time that the technology gap was closing and the intensity of competition was increasing among OECD countries, the Third World was demonstrating a growing degree of industrial strength. Through the 1960s and 1970s, developing countries increased their share in world manufacturing value added (from 8.1 per cent in 1967 to 10.9 per cent in 1982). More importantly this was coupled with a substantial rise in their world share of manufactured exports (from 4.5 per cent to 9.2 per cent over the same period) (UN, 1983, Table 9, p.14).

TABLE 3.1

Exports of Manufactures (SITC 5-8 less 68) by Selected Developing Countries, 1970-1980

Country or territory	Average annual growth rate (percentage) 1970-1980	1978-1980
Republic of Korea	43.1	18.3
Hong Kong	19.9	25.2
Singapore	34.3	41.3
Brazil	35.9	33.4
India	17.2	10.0
Mexico	20.2	-
Argentina	27.1	5.4
Malaysia	37.1	32.8
Kuwait	36.9	38.4
Thailand	50.7	36.8
Pakistan	9.6	22.7
Philippines	31.4	31.3
Other countries	25.2	-
All developing countries[a]	26.5	26.0

Source: adapted from UNIDO (1984)

[a] Seventy countries.

There are a number of significant points to note about the export performance of developing countries over this period. First, as is well known, a small number of NICs in Asia and Latin America accounted for the large majority of exports - the top eight countries were responsible for about 70 per cent of the total by 1980. In the process of expanding their market share, the NICs (and a group of about 25 other countries) achieved historically high rates of overall annual growth - 26.5 per cent between 1970 and 1978 (See Table 3.1). Secondly, though traditional labour-intensive exports such as clothing, textiles and leather goods accounted for a large share of total exports (about 53 per cent in 1978), the product mix began to diversify significantly in the 1970s, with Third World exporters achieving notable gains in electronics-related products and certain categories of non-electrical machinery (viz agricultural machinery, textile machinery and machine tools). The

NICs dominated in all of these categories, but in both garments and electronics other countries also began to make an impressive showing. A third point is that developed countries were important markets for Third World exports, both overall (58.4 per cent in 1980) and in specific categories such as clothing and electronics. This suggests that in some important product categories Third World countries were very dependent upon retaining access to OECD markets.

This pattern of Third World exports had a notable impact on development thinking and on the posture of the advanced economies towards the Third World. The apparent success of the export-oriented policies adopted by the NICs in the 1960s and 1970s led many smaller and poorer developing countries to introduce similar policies in an attempt to follow the same path. For instance, many established Export Processing Zones in order to capitalise on their low wages to capture offshore assembly investments by TNCs - between 1978 and 1980 the number of Export Processing zones increased from 220 to over 350, with most located in the Third World. Multilateral agencies such as UNIDO, the World Bank and the IMF supported and encouraged those efforts, and high rates of growth for manufactured exports were forecast for many countries, including the predominantly agricultural economies of Africa in the 1980s.(2) For instance, Kenya's imputed annual rate of growth of manufactured exports for the 1980s was set at 23 per cent, in contrast to a rate of 6.8 per cent achieved between 1973 and 1980 (Godfrey, 1983).

Moreover, the diversification of the export mix away from traditional labour intensive products toward products with a higher technological content and the ability of some countries to export technology as well as products was seen as evidence of growing Third World industrial competence and of a narrowing of the technological gap between the First and the Third World. This was heralded as a sign of a process of "restructuring" in the international division of labour in the world economy whereby developed countries would move out of the production of mature products into more sophisticated goods to make way for the developing countries.

From the more sanguine perspective of the developed countries, the export success of the Third World was viewed with trepidation particularly as their own growth rate began to slow and unemployment levels began to rise. Much of this concern was due to the concentration of Third World exports in particular product categories, which was seen as the principal cause of the long term decline of output and employment in domestic industries such as textiles and garments. However rather than relinquish their market share to low wage imports, industrial firms in the developed countries began to pressure their governments for increased protection. This has subsequently led to a rise in the level and scope of tariff and non-tariff barriers levied against imports from the Third World.(3) Quite apart from the problems posed by microelectronics, as the 1970s drew to a close, developing countries were finding it increasingly difficult to sustain the high rates of export expansion that they had enjoyed earlier and which they had been led to expect would continue (see, for instance, Balassa, 1980).

Implications of microelectronics for international competitiveness of Third World exporters

The previous discussion emphasized the importance now attached by developing countries to export expansion and promotion in their development strategies and the growing role of technical change as a determinant of increasingly fierce international competitiveness. In this context it is understandable why so much attention was given to the implications of microelectronics for Third World comparative advantage in the early literature on the topic (see Hoffman and Rush, 1980 and Kaplinsky, 1981). Automation and product innovativeness in the North were seen as posing a major threat to the primarily low wage based competitive advantages of developing countries. However, at the same time, the experience of the NICs, particularly in the electronics sector, has more recently underlined the fact that the flexibility and relative accessibility of the technology can also create new market opportunities for countries and firms astute enough to spot product niches and fill them successfully.

Unfortunately the available empirical evidence is far too limited to allow any final conclusions to be drawn on the extent of application of these arguments. The number of studies is small and as yet the limited degree of diffusion of the technology in many sectors means it is still too early to draw conclusions about how technological developments in the North will affect Third World comparative advantage. One aspect that the studies do make clear however is that the technology factor, though important, is only one of the elements that need to be considered at the point of policy formulation. Other factors, such as TNC strategies, the global trading environment, and location specific comparative advantages , all interact with technology in a way that makes it difficult to forecast trends on an *a priori* basis.

Because of this we have chosen to illustrate the trade implications of microelectronics by briefly exploring the evidence that is available on trade-related developments in three sectors - machine tools, clothing and electronics. There are good reasons for using these three sectors in this way. On their own they account for a significant share of Third World exports. They also exhibit a set of characteristics common to a larger number of sectors and countries and therefore provide some basis for generalization. Moreover, a number of Commonwealth developing countries, at various stages of development, are already engaged in the manufacture of these products for export, eg India, Singapore, Sri Lanka, Jamaica, Bangladesh, Malaysia and Barbados.

CNC lathes: a challenge to the NICs

In Chapter 2, we noted that CNC lathes have become increasingly competitive and as a result the market for conventional lathes is rapidly declining in the developed economies in both absolute and relative terms. This poses a serious challenge to firms in countries such as Taiwan and South Korea who regularly export a majority of their machine tools to the North. These firms must either switch to the production and export of CNC lathes or ultimately be squeezed out of the market.

Problems may also arise for Latin American firms who tend to export a majority of their lathes to other large developing countries. Demand for CNC lathes is rising in these markets as well and thereby attracting the attention of Japanese lathe producers, most of whom have set up marketing or production subsidiaries in Latin America. In time, Latin American lathe producers will also have to switch to the production of CNC lathes to retain their export markets.

In short, microelectronics, and the technical skill and commercial acumen of Japanese machine tool firms, have effectively eliminated NIC competitiveness in a sector where they had made an impressive showing (with an 18 per cent share of the US market in 1980), and where conventional comparative advantage theory suggests they should continue to do well.

Can the NIC producers make the switch to the production and export of CNC tools? To do so several new barriers to entry (determined partly by the technology and partly by the strategy adopted by the Japanese) have to be overcome.

First, an electronics design capability has become a crucial source of competitive advantage and is much more important now than the "seat of the pants" mechanical engineering skills and low wages which allowed NICs to get their initial foothold in the industry. Hence NIC firms must acquire and apply these skills.

Not only are electronic engineering skills necessary, so too is an expertise in computers, in materials handling and in advanced power train design. Moreover, individuals with these skills have to be brought together in a multi-disciplinary design team that works together in a way which differs from the approach commonly adopted in the Third World. The application of these skills necessarily means that more resources have to be devoted explicitly to R&D activities; an activity which had not previously been a feature of the competitive strategy of NIC firms.(4) The rate and scope of technical change is increasing as new product designs, spread across a wider range of products, are emerging much more quickly than in the past - every two to three years compared to eight years previously. By extension this means licensing and technology acquisition must be pursued more vigorously, and close design relationships must be forged with NC control unit suppliers.

Second, in order to match the price competitiveness of Japanese producers, low wages are no longer sufficient since the share of labour in total costs has declined. Instead NIC producers must strive to achieve scale economies in those product categories where their exports are concentrated. Current NIC output levels tend to be well below minimum efficient scale, and hence exports are essential since domestic markets are usually far too limited.(5) Achieving scale economies depends not only on penetrating export markets but on the adoption of best practice production techniques as well. Many Japanese firms are moving rapidly into the use of robots and flexible manufacturing systems in the production of machine tools. The largest Korean and Taiwanese firms have been forced to follow suit and although they are not as automated as the Japanese, they do make extensive use of computer technology. And as pointed out earlier, large scale component procurement is essential to achieve cost reduction, both because of the unit cost savings that can be achieved and because the control unit now accounts for a much larger share of final costs.

Third and related, an international marketing and after sales network has to be established. This is essential to gain feedback on user needs and to establish a reputation in the market - both aspects having risen in importance directly because of the success of the Japanese strategy.

Jacobsson (1985) suggests that out of a hundred or so lathe producers surveyed in Argentina, Taiwan and South Korea, only a dozen have been able to enter CNC lathe production and of these only two have demonstrated a potential capacity to overcome the barriers described above; although whether they can be competitive in the longer term as the technological frontier continues to move forward is another question. He attributes the likely success of these two producers (in Asia) and the likely failure of the others (in Latin America) in part to the types of intervention policies that the respective governments have pursued rather than to any inherent technological advantages. He rejects the conventional argument for uniform protection as a basis for intervention and calls for a product- and indeed a firm-specific form of support not only in terms of tariffs but also via a direct subsidy to R&D and production. Subsidies to R&D are needed to allow local firms to amass new skills and thus to be able to respond to the high degree of design intensity that is an essential aspect of competition in machine tools. Production subsidies on the other hand will contribute to the equally important attainment of scale economies both in output and in marketing. The likely success of leading firms in South Korea and Taiwan is attributed to precisely these forms of intervention. Argentina's strategy of using trade policy as its main instrument has had the counter effect of encouraging firms to run down their own design efforts and rely instead on licensing and low volume production - a strategy which makes the firms distinctly uncompetitive in international markets.

Clothing industry: long-term problems for new entrants

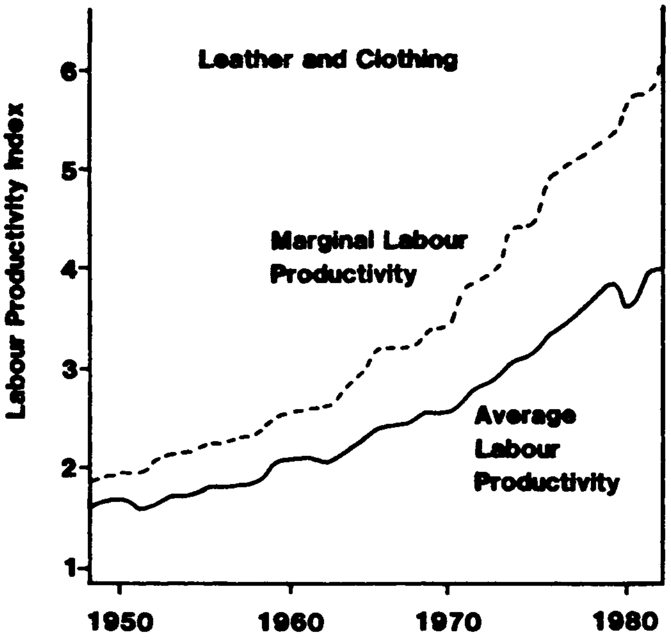
The export of clothing is an important source of foreign exchange and employment for a much wider group of developing countries (including those from the Commonwealth) than is the export of machine tools. Many smaller countries hope they can repeat the export success of the NICs, and are pursuing the creation of an export oriented clothing industry. In Chapter 2 we noted that CAD and CNC technologies used in pre-assembly activities are diffusing rapidly among the large firms in the North. However, due largely to technical reasons, the actual assembly of clothes has not yet been automated. Since assembly accounts for 80 per cent of value added, relative wage rates continue to be the major determinant of competitive advantage in the clothing industry and here the developing countries still enjoy a distinct advantage. As a result, there has been no microelectronics induced, across-the-board, shift in competitive advantage in favour of the North - though some very product specific examples of this have occurred.(6)

This means that for some time yet Third World countries will continue to enjoy a significant cost advantage in international clothing markets that will not be eroded by automation in the developed countries. In fact, by far the most important constraint on export growth in the short to medium term, lies in the rising tariff barriers erected by the importing countries. Since 1977 these barriers have sharply limited the rate of growth of Third World clothing exports. The smaller, newer entrants have taken much of the brunt of these constraints and we would argue it unlikely that the importing countries will ever allow exports from these countries to grow as fast or reach the same level as those from the NICs.(7)

At the same time, as the high rate of diffusion of CAD systems and CNC cutters demonstrates, the pace of technical change in the clothing industry has begun to increase perceptibly after a long period of quiescence. Though microelectronics-based technical change does not yet play a significant role in determining the international competitiveness of the industry in the North, the situation is evolving rapidly. New, electronics-based firms are entering the equipment supply market, thereby increasing the rate of change and enhancing prospects for raising productivity growth rates. For instance, as Figure 3.1 shows, the marginal productivity of new investments in the U.K. clothing industry increased substantially over the 1975-1980 period. Much of this rise is attributable to investment in new, largely microelectronics-based, technology among the larger firms. The same factor is at work in the US. The commitment by MITI of $52 million to the development of flexible manufacturing systems for clothing assembly is a particularly impressive example of these efforts. Moreover, concentration is increasing, and the larger firms have shown themselves very willing to innovate and to provide support for a long term drive to increase the level of automation. The latter will allow them to reduce their dependence on offshore assembly in the future.(8) As noted in Chapter 2, these efforts are being augmented by a very considerable degree of publicly supported R&D programmes, all designed to overcome the technical barrier to automation in the assembly stage.

Taken together, these developments suggest a scenario in which average productivity growth in the North wil rise steadily but slowly to the mid 1990s or so. Despite this rise in the competitiveness of the North, we believe that most developing countries should continue to be able slowly to expand their clothing exports within the constraints defined by protection. However, as flexible manufacturing systems begin to emerge and be diffused among the developed countries, the competitive advantage of Third World firms could begin to be seriously eroded unless they start now to upgrade their technological levels and reverse the decline in productivity that has characterized the performance of all but a few NICs since 1973.(9)

Figure 3.1: Marginal and Average Labour Productivity in Plant and Machinery, UK Leather and Clothing Industry, 1948-82



Source: Rush, H and Soete, L 1984

The NICs should be well placed to do this, given their already demonstrated capacity to respond to changing market conditions by improving quality and moving "up market" in the clothes they export. They will nevertheless have to devote more attention to technology than in the past - though whether they need to pursue automation to the same degree as in the North remains to be seen. Somewhat greater questions arise regarding the response capacity of second tier countries such as Malaysia and the Phillipines and of even smaller exporters such as Sri Lanka and the Caribbean economies. These countries will have to overcome the twin obstacles of import barriers and a moving technological frontier if they expect the clothing industry to provide expanding employment and be an economic stimulant in the longer term. The slow diffusion of automation technologies in the clothing industry in the developed countries does offer a measure of hope that adjustments can be made. However there is also cause for concern regarding the long term implications for newer entrants.

Semi-conductor industry: unbridgeable barriers to entry

In Chapter 1 we gave a number of examples which suggested that even though barriers to entry were growing, many developing countries could still hope to gain entry to export markets in various parts of the electronics sector. This situation stands in sharp contrast to conditions prevailing in the heart of the electronics complex - the semi-conductor industry - where barriers to entry are already extremely formidable. There are a number of reasons for this.

First, in sharp contrast to earlier periods, start-up investment costs are now very high, ranging between $50 million for an MSI wafer fabrication facility, to more than $100 million for an LSI operation. The only entities sufficiently strong to undertake such high risk investments are either the huge conglomerates who currently dominate the industry or governments willing to provide the necessary support to a public or private sector venture.(10)

Second, due to the substitutive nature of competition between successive vintages of device, chip manufacturers must stay at or near the forefront of product technology or else rapidly lose their market share.(11) Consequently, R&D costs are also very high and semi-conductor firms must spend 7-10% of their sales on R&D - which for the top 10 US firms meant an expenditure of nearly $800 million in 1982 (Bessant, 1983).

Third, to establish a facility capable of undertaking the full range of design and production activities a large number of well trained and highly specialised scientists, technicians and electronics engineers are required. Moreover, a wide variety of specialist inputs suppliers are also needed to provide the chip manufacturer with wafers, electronics chemicals, special equipment, etc. Only a few highly diversified industrial economies are able to meet these demands.

Finally, the NICs and second tier developing countries traditionally entered into the export market via final stage assembly under TNC control. This route of entry would now appear to be closed. TNC investments in new IC production facilities in the Third World have slowed down considerably since 1974. Most current investments are either in highly automated plants in the OECD countries or in expanding capacity in existing offshore sites. Hence, it is now extremely unlikely that most TNCs would consider opening new production sites in new countries on a scale large enough to make a substantial contribution to the host economy. Low wages are no longer the advantage they once were in attracting offshore investments, and countries like Sri Lanka, Bangladesh and Pakistan which have hopes of entering the IC market in this way are almost certain to be disappointed. The same goes for the Caribbean island economies, such as Jamaica and St. Vincent, which have recently been attempting to woo semi-conductor firms with the attractions of a low paid, English speaking work-force close to the US. The objective conditions governing the location of IC facilities by TNCs have permanently shifted against these countries.

Major questions also still remain over the capability of the second tier developing countries such as Malaysia, Indonesia, the Philippines and Barbados, to gain much further advantage from their heavy dependence on TNCs in the electronics sector. Semi-conductor firms do continue to operate in these countries and facilities are being upgraded in response to the current world shortage of devices. The extensive plans that TNCs have for the introduction of automated assembly, test and packaging equipment in Malaysia, as reported by Malaysian Business (1984), are a case in point. A priori we would suggest that there is still a good deal more that could be done to encourage TNCs to go further in this direction. However, there is an even greater concentration of TNC effort to create regional production, testing and distributional centres in South Korea, Singapore, Taiwan, Brazil and Mexico. If the second tier countries wish to develop their electronics industry further, they will have to complement their efforts to exploit TNC presence by pursuing policies to also upgrade the capacities of nationally owned firms rather than relying on TNC initiatives alone.(12)

The trends towards a rapidly moving technological frontier, regional concentration of TNC investments and expanding national capabilities within the NICs (and at most one or two other countries), which are evident in the semi-conductor industry, almost exactly parallel the developments in the machine tool and clothing industries reviewed above. Smaller, less technologically advanced developing countries are in danger of being permanently excluded from gaining access to the most rapidly growing parts of the electronics market. Whether or not this is a good or a bad thing for individual countries in any objective sense must remain an unanswerable question since such access is unlikely ever to occur.

From a policy perspective this does not mean that smaller countries should give up all hope of developing their own component industries. Quite the contrary, it makes the development of a national component design capability essential, since the key to exploiting the technology's application flexibility will rest on having the ability to design the circuits. The design technologies associated with devices such as gate-arrays will almost certainly be accessible. Even production for the domestic market might be feasible if "silicon foundaries" are set up - perhaps on a regional basis. But the hopes of many countries that they would be able to participate in the export bonanza that is accompanying the explosive growth of world demand for electronics must now be set aside.

As we noted, despite the gloomy picture in semi-conductors, the present conditions governing entry into that part of the market differ significantly from those in the sub sectors reviewed in Chapter 2 - consumer electronics, computers and software - where the technical and economic constraints on participation by developing countries are much less severe. Four characteristics are common to all these subsectors (though there are of course also some major differences). First, the rapid diffusion of microelectronics within the electronics complex means that a very wide variety of product niches are emerging with characteristics which could allow much greater participation of Third World firms. Secondly, the successful exploitation of these product niches depends much more on product design capabilities than on process technology (though obviously the latter is important in some categories - eg the use of automatic insertion technology in colour TV production). Since product design technology can be acquired and assimilated more quickly and at lower costs than process technology, developing countries are better placed to take advantage of the opportunities that might exist, for instance, for the local adaptation of imported systems. Thirdly, though TNCs do play a major role in some segments of each of these subsectors (for instance in mainframe and mini-computers or in state-of-the art video tape recorders), small firms enjoy distinct advantages in responding to or anticipating specific and/or changing market demands in many product categories. Finally, for a number of products, efficient scales of production are quite low; this means that 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 early in their history. The big question that remains for the future is whether or not the trends in technical change, increasing concentration and rising capital costs, which are now dominant in the semi-conductor industry, will eventually emerge in these other sectors as well. It is an issue which will need careful scrutiny by governments before they embark on export marketing.

Some generalisations

The evidence presented above and in Chapters 1 and 2 provide some grounds for generalisation - though obviously must be treated with caution. Manufactured exports from developing countries tend to be concentrated in three categories - traditional labour-intensive products, such as garments and textiles; electronics-related products, many of which are also labour-intensive, but in some cases involve a fair degree of technological sophistication; and a variety of products which fall generally in the area of machinery and mechanical engineering but range from machine tools to simple agricultural implements.

Though no across-the-board sectoral comparisons are possible at this time, the rapid diffusion of microelectronic product and process technologies in the non-electrical machinery and mechanical engineering sectors, suggests that the technological frontier is beginning to move rapidly ahead in some sectors of major importance to the Third World. Whether or not this means that the technology gap between North and South is widening depends on the sector and the types of countries one is discussing. In some parts, a select group of more advanced developing countries are probably operating as close to the technological frontier as their competitors in the weaker industrialized countries, in terms of their *use* of technology. This suggests that the gap between the NICs and other developing countries is widening while that between the NICs and the North is perhaps narrowing somewhat. However, leaving aside these areas, we do feel that the diffusion process mentioned above implies that Third World exporters do indeed face a *potential* erosion of their comparative advantage. Nevertheless, the fact that advanced technology is generally being introduced in a piece-meal fashion by developed country firms means that the gap is widening by increments rather than by quantum leaps. For those developing countries already able to export successfully to developed country markets, the gap may still not be too great to cross - though it is impossible to say whether it can be crossed only if Third World firms also use advanced technology. Clearly in the case of machine tools, and probably in other types of complex machinery, the use of microelectronics is now, or soon will be, essential to retain competitiveness. In our opinion, the machine tool industry is exceptional only to the extent that it moved into the use of CNC technology much earlier than did other sectors - all other machinery will eventually go along a similar path, and if developing country exporters are going to remain competitive in the markets of the North they must follow suit.

The machine tool case raises another general set of issues. We have seen what has happened in the case of lathes. A product which was relatively mature and where the pace of technical change had been low has now been transformed by microelectronics. This is precisely the sort of product category where observers like Lall (1980) and others have suggested that developing countries stand their best chance of gaining entry to export markets by building up the necessary capabilities through the learning process. The incorporation of microelectronics into such products adds a whole new dimension to the "learning" problem.

For example the principles of operation of machinery using microelectronically based control units are simply not transparent in the way that electro-mechanical technology was. 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. In this case the practice of reverse engineering, which is a source of much learning in the machinery industry in the Third World, now becomes a much more complicated task that is absolutely dependent upon the availability of a pool of adequately trained specialists and sufficient R&D resources. Obviously, "learning" in this situation is by no means impossible but it does present new challenges that firms have not had to face before. This has implications for the innovation and training policies pursued by Third World firms as well as for the government policies in the area of higher education and subsidies to R&D.

The uneven process of diffusion of automation in the clothing sector raises an entirely different set of issues, since it suggests that in some sectors developing countries will enjoy a "breathing space" during which they can continue to rely on traditional sources of competitive advantage to retain their market shares. What is important about this is not just that there is such a breathing space but that it may eventually diminish as microelectronics penetrates even the most technologically stagnant industries. Hence Third World exporters (current and potential) must use the breathing space afforded by uneven diffusion in the North to begin to upgrade their product and process technology. Once again, it may be that the use of microelectronics or automation technologies is not necessary to achieve substantial gains in productivity and competitiveness. Indeed it is almost certain that firms in developing countries will be able to achieve significant gains by pursuing improvements in X-efficiency, in product design and via the use of more efficient conventional techniques. However, if the future does lie with microelectronics, then firms clearly need to enter into the leaning 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 rather than on straightforward comparative costs.

The next general point is that if developed country markets become more difficult to penetrate without a sophisticated technological capability, Third World exporters may increasingly have to look to South-South trade as a way of maintaining their export growth. South-South trade has of course grown considerably in recent years and is already very important in certain sectors. Third World firms are believed to enjoy a unique set of advantages over First World firms in selling to these markets. Given the similar operating, infrastructural and factor price conditions to be found in developing countries, it is arguable that products successfully designed by local producers for local markets in one Third World country will find export market in other Third World countries, particularly in the same region. These advantages may now have to be more systematically cultivated - a particularly difficult task in times of recession when demand in the Third World is depressed. But it may prove to be one of the best ways that exporters can continue to maintain an export capability while they strive to master the new technology that will allow them to penetrate the markets in developed countries.

Finally, it almost goes without saying that when one is talking about Third World exporters of manufactured products, particularly non-traditional products, one is largely talking about the NICs, and in certain products about the second tier developing countries. Both categories face a more difficult task in maintaining their hard won position in export markets in the face of the microelectronics revolution. Chances are, however, that a number of these countries by virtue either of their size (such as the case of India, Brazil and Mexico) or of their already well developed industrial base, will be able to survive and even prosper intentionally. However, the question of whether the bulk of the poorer developing countries should adopt or continue to pursue export-oriented industrialisation strategies clearly becomes more problematic. The difficulties appear considerable - and the future and the options remain ill-defined.

Section 3: Economic Impacts at the level of the Firm

Directly related to the issues raised in the discussion on international trade are questions about the need for and the impact of the use of microelectronics technologies by Third World firms. Apart from the NIC experience in the electronics sector, there is almost no empirical evidence relating to the use of microelectronics by Third World firms - even though the technology is obviously being deployed to a limited extent in certain sectors in certain countries. As time passes, a growing number of firms will almost certainly have to confront the choice of whether or not to introduce microelectronics technology if they are to remain competitive either internationally or on the local markets. It is a quite separate question as to whether or not government policies should encourage the use of microelectronics and MRIs by local firms. We do not address this issue here. What we do want to do however is review the evidence on firm-level impacts to highlight some of the issues which are likely to be relevant to decisions facing Third World firms and governments in relation to the choice of technique concerning microelectronics.

Once again the evidence primarily relates to the use of MRIs in the developed countries. The literature on this raises three general issues. First, the introduction of microelectronics technology invariably has multiple effects on the firm - in terms of the benefits gained as well as the costs incurred and adjustments involved. Second, the scale and scope of these effects rise sharply where higher levels of automation are involved. Third, and perhaps most importantly, there are many factors which affect the ability of the firm to introduce and use the technology efficiently. All three of these aspects bear directly on the issues raised by the introduction of the technology in Third World countries. In this section we first review firm-level gains associated with the introduction of MRIs under five categories - savings on labour costs, savings on capital costs, reductions in product lead-times, savings on material usage, and improvements in product quality. We then discuss the impacts on these and other categories where higher levels of automation are involved; and finally, we consider the skill implications associated with the use of MRIs.

Savings on labour costs

The use of MRIs can affect unit labour costs in two ways - via the reduction in direct and indirect labour inputs per unit of output; and by allowing less skilled and therefore lower cost labour to be used. The available evidence suggests that such savings can occur at all skill levels in all phases of manufacturing. However, the extent of net labour displacement that results from improvements in labour productivity varies widely as we shall see in the next section. Of particular interest here are the effects on skilled labour usage, since skilled labour availability is often a constraint on production in developing countries. Indeed this does appear at the present time to be the most widely affected category. Techniques such as CAD systems or CNC equipment are direct substitutes for skilled labour and can be introduced more or less off-the-shelf, whereas the use of automation technology to replace unskilled labour (via the use of robots or FMS) is often a much more costly affair and is diffusing more slowy. Since saving on unskilled labour is not likely to be a principal reason for the use of MRIs in developing countries we do not give any examples of this type here.

TABLE 3.2

Productivity of CAD systems in Selected UK and US Firms

Activity	Location	Primary use of CAD	Average productivity ratio
Integrated circuits	US	Design	2:1 after 6 months
Automobile components	UK	Design	3:1 after 12 months
Plant design	UK	Draughting	3:1
Process plant	UK	Design	NI
Printing machinery	UK	Design/ draughting	>2:1
Automobiles	UK	Design	3:1
Computers - pcb's	UK	Design/ draughting	>5:1
Petroleum exploration	UK	Design	2:1
Aircraft	US	Design	2.5:1 in 1979 3.32:1 in 1980
Public utility	US	Draughting	3:1

Source: adapted from Kaplinsky (1982)

Several studies on the use of CAD systems show that the average gains in labour productivity are in the range of 3:1. Kaplinsky (1982), Arnold and Senker (1982) and Hatvany et al (1981) document this trend for the US, the UK and Sweden and also point out that where CAD systems are used for basic draughting or for redesign activities, labour productivity improvements can reach as high as 20:1 and even 100:1. Table 3.2 documents this range of gains in labour productivity across a number of sectors. Similarly strong evidence is available in relation to the use of CNC machine tools. Studies by Jacobsson (1982), Remp (1982) and Senker (1981) for the UK, Sweden and West Germany show that average gains in labour productivity range from 2:1 to 5:1.

In one of the few studies on the use of machine tools and CAD systems in developing countries, Chudnovsky (1984) found that savings on unit labour costs were an important, but not the most important, reason for acquiring the technology. Table 3.3 sets out the evidence for one firm where labour savings were an important determinant of the choice of technique in relation to CNC machine tools. Where CAD is concerned, artifically high wages for draughtsmen meant that the initial use of CAD by Argentinian firms resulted in labour productivity gains of 3:1. These wages have now fallen and the technology can no longer be justified on labour cost savings alone.

TABLE 3.3

Costs Per Hour and Per Piece for Conventional and NC Lathe in Argentina (in Argentine pesos)

	NC lathe (1)	Conventional lathe (2)	(1):(2) x 100
Cost of lathes[a]	487	127	383
Labour costs[b]	153	153	100
Tools used	88	25	352
Electric power	75	25	300
Total cost per hour	803	331	243
Total cost per piece[c]	1.34	4.95	27
Lathe per piece	0.81	1.89	43
Wages per piece	2.55	22.95	11
Tools per piece	0.15	0.37	39
Electric power per piece	0.12	0.37	32

Rate of exchange US$ 1 = 41 Argentine pesos

Source: Chudnovsky (1984)

[a] $\frac{C}{TH} 1 + \frac{i}{2} (T + 1)$
C (NC lathe = $a 4,715,000 (115,000 US$)
C (Conventional lathe) = $a 1,230,000 (30,000 US$)
i (interest rate) = 20% per year
T (depreciation time) = 5 years
H (annual hours worked) = $a 3100 (two shifts)

[b] Wages + fringe benefits + social charges

[c] 100 pieces are made in 10 minutes with the NC lathe while 100 pieces are made with a conventional lathe in 90 minutes

Even where less sophisticated equipment is involved, the use of microelectronic control systems leads to considerable productivity gains as the control unit can take over many operator functions and increase the rate of output. An example relevant to developing countries is the clothing industry, where a survey in the US and Europe of 50 cases where microelectronically controlled sewing machines replaced conventional machines, showed labour productivity improvements ranged from 18 per cent to 135 per cent. The best previous gains associated with non-electronic technical change had been in the 6-10 per cent region (Hoffman and Rush, 1986). Use of these machines in developing contries had similar effects though the gains were not as great because of lower wages. Skilled labour, principally technicians, is also saved as a by-product of the use of process controllers. For instance, the British Sugar Corporation introduced microprocessor controllers on its sugar evaporator and crystallizer units and improved technician productivity by 75 per cent (Bessant, 1982). Similar savings no doubt occurred in relation to the range of textile innovations discussed in Chapter 2, while Senker (1983) identified examples in the paper packaging industry, in the foundry sector and in the aluminium industry where firms also able to save on the use of technicians. Advances in testing and quality control technology are being introduced into virtually every industry. These devices allow firms to carry out a wide range of test procedures which in addition to reducing the need for skilled testing personnel can also have a notable impact on product quality. From the developing country perspective this is an important advantage since it may imply less need for these types of scarce personnel and lead to higher product quality.

There are obviously many other examples of labour productivity gains which could be provided. One final point should be noted. Machine or process specific gains in labour productivity can be very considerable at the micro level. But when considered at the level of the firm, or even of the plant, they often become diluted. As we shall see, this is not the case where higher levels of automation are involved.

Savings on capital costs

In light of the long term decline in capital productivity in the developed countries, the alleged capital savings effects of microelectronics could be even more significant than gains in labour productivity. Reduction in capital unit costs would also be an important benefit for developing countries given the high opportunity cost of capital. So far, however, apart from the electronics sector, the evidence on gains in capital productivity resulting from the use of MRIs in intra-activity automation is equivocal. Many items of machinery using microelectronics are considerably more expensive than conventional techniques and in the absence of multi-shift operation, capital savings appear to be low. For instance, electronic sewing machines can be anywhere from seven to 40 times as expensive as conventional machines, while the gains in labour productivity do not often justify their use on multiple shifts. Some other examples of the high capital cost of MRIs are given in Table 3.4. Investment costs are not the only element in capital unit cost calculations but there is little evidence available on the effect of intra-activity automation on working capital costs - except in the case of products using electronic components which replace more numerous and usually more expensive non-electronic components.

In the future, capital unit costs for many types of MRI are expected to decline as the production of these items becomes more automated - as is currently the case with machine tools. However, the most important sources of capital savings arise when firms move to more advanced levels of automation; these are discussed below.

TABLE 3.4

Comparison of Costs of Installing Equipment Incorporating Microelectronics

	Total cost £,000	Electronics as proportion of total cost
NC machine tools	10- 50	up to 50%
CNC machine tools	25-100	up to 50%
Industrial robots	20- 50	up to 50%
Process instrumentation, control loop (PLC)	1- 10	10-20%
Custom design machine controls	5- 10	10%
Automated foundry line (microprocessor controlled)	£2.5m	5%
Metro line (incorporating high levels of automation)	£285m	10-30%

Source: Bessant (1982)

Reductions in product lead times

Substantial reductions in product lead time have been well documented, particularly where CAD and CNC systems are involved. Rapid task execution, elimination of separate steps in production, and overall economies in time combine to improve greatly a user firm's ability to respond quickly to changing patterns of consumer demand. These have proved to be a very important benefit to firms operating in sectors where rapid response and quick turnaround are essential competitive strengths in the face of lower cost producers in developing countries who inevitably face long lead times because of geographical distance. Reductions in lead time of 50-90 per cent in the preparation of designs, prototypes and products are commonly reported in the literature (Kaplinsky, 1982; Ayres and Miller, 1983; and Hoffman and Rush, 1984). Gunn (1983) reports a number of typical examples from CAD users - General Motors has reduced the time it takes to design a new automobile model from 24 to 14 months; another company reduced design time for custom valves from six to one month.

Savings on material usage

Greatly improved process control systems have facilitated quite sizeable reductions in materials use. This has been particularly important in sectors where material costs are a high proportion of total costs. For instance, in the production of garments, fabric accounts for 50 per cent of total costs. The use of CAD systems has allowed material savings of up to 12 per cent - for firms whose annual material bill can run into tens of millions of dollars, such savings can be quite significant (Hoffman and Rush, 1986). Along the same lines are the very substantial energy savings which can result from the incorporation of microelectronics into process controls to monitor and optimize energy usage. In oil-deficient developing countries this could be of vital benefit since continuous process industries consume a considerable quantity of energy. Other inputs can be more efficiently utilized as well, due to process control application. For instance application in the metal working sectors in the UK yielded reductions in scrap of 50 per cent (Wilson, 1984). Since gains in material/input use achievable from the use of process control can be quite significant, it is arguable that provided capital costs can be contained, process control applications should be pursued wherever possible in developing countries.

Improvements in Product Quality

There are a wide variety of product related effects associated with the use of microelectronics. For instance, the use of MRIs facilitates the more efficient production of commodities with consumption characteristics (eg product uniformity and reliability) valuable to large scale consumers of manufactured intermediates - tin cans, electrical components, glass containers, automobile parts, etc. In these sectors, significant costs are incurred as a result of high rejection rates (10-15 per cent in the glass container industry), which result in lost work-in-progress due to the time it takes to observe and correct a fault in the production process. CNC controls facilitate the use of much more accurate cutting and forming techniques which greatly improve uniformity. This is clearly an essential factor for industries parts which must be machined to very high degrees of tolerence. Moreover, a high degree of product uniformity and quality is crucial to maintaining market share in the mass produced final consumer products which some NICs are beginning to manufacture.

The importance of product quality effects is likely to be significant for developing countries, particularly for firms involved in producing components on a sub-contracting basis. Increasingly, large firms, particularly TNC subsidiaries, who source components locally, are demanding product characteristics and tolerances which can only be met by the use of CNC tools. This was found to be the case in both Argentina and Brazil by Chudnovsky (1984). Developing inter-industry linkages is a major objective of industrialization policy in the Third World and achieving it is often hampered by the low quality of component suppliers. New techniques such as CNC tools may be the only way of achieving linkages in the future, particularly in markets where TNCs operate.

Systems level gains in automation

One of the main arguments in Chapter 2 was that the industrial application of microelectronics was evolving towards higher levels of integration and automation. Introduction of MRIs into existing production processes on a stand-alone or retrofitting basis can, as we have seen, yield considerable benefits. However the full potential of the technology is not realised until systems begin to be linked together, since previous equipment or process designs inevitably introduce a set of constraints on the degree of integration that can be achieved. Evidence from the case study literature bears this out graphically. The linking of CAD and CNC machine tools is the most advanced form of inter-sphere automation, and their linked use yields step-jump gains in productivity over their use in stand-alone installations. For instance, the US aerospace engine manufacturers Pratt and Whitney, report a 6:1 reduction in labour usage using CAD as a design tool. Yet when they linked the system to the operation of CNC machine tools this ratio went up to 30:1. At the same time, product lead times were improved by a factor of 50. Table 3.5 shows similar phenomena in relation to the clothing industry.

TABLE 3.5

Firm Level Impacts of Computer-Aided Design and Computer Controlled Cutting

Area	Impact	
Material saving	With CAD	4-6% saving on total material costs
	With CAD/cutter	4-10% saving on total material costs
Reduction in labour use	With CAD	50-70% reduction in grading/marking labour costs
	With CAD/cutter	25-50% reduction in cutting labour costs
Training time	With CAD/cutter	Reduced from years to months Tasks virtually totally deskilled
Lead time/throughput	With CAD/cutter	Reductions of up to 50% on total lead time Task reduction from days to hours on design and cutting
Flexibility	With CAD/cutter	Increased product range Rapid design changes Better response to changes in demand
Downstream effects on assembly	With CAD/cutter	4-10% saving on sewing time Improved quality due to more accurate cutting
Rationalisation	With CAD/cutter	Substantial savings due to process and plant reorganisation Reduced transport, indirect labour, supplies and inventory costs Often as high as material or labour savings

Source: Hoffman (1985)

It is at this degree of integration where capital savings begin to become apparent. Substantial savings in fixed capital costs can occur from a variety of sources such as increased capacity utilisation due to multiple shift working and reduced overtime payments. These savings have been analysed for the metal working industries in the US by Ayres and Miller (1983) where the effective utilisation of conventional machine tools as a proportion of theoretical capacity is only 6 per cent in low volume shops, 8 per cent in mid volume shops and 22 per cent in high volume mass production industries. With the introduction of more integrated systems capacity utilisation can go up dramatically - where CNC systems are used the gains range from 11-16 per cent for different levels of output. When flexible manufacturing systems are introduced, these increase to 39-52 per cent.

Working capital costs can also be reduced with flexible automation technologies by increasing the rate of throughput of work-in-progress and reducing inventory costs through the more efficient scheduling of the production of different product mixes. These gains are important since the value of inventory and work-in-progress often far outstrips investment in machinery and buildings - sometimes by as much as two or three to one. Among many examples, Gunn (1982) reports on inventory savings of up to 30 per cent by more than 10,000 US firms using the computer based scheduling techniques discussed in Chapter 2.

By far the most impressive set of systems-level gains arise when flexible manufacturing systems are introduced. As we noted earlier, these systems tend to affect both mass production and batch production techniques. In batch produced goods, there are usually low levels of product standardisation and a high degree of customer specificity. These conditions demand flexible multipurpose tools which can be used to produce a range of products. Historically, flexibility has been achieved at the expense of efficiency. Product change-over is very time consuming and the associated fixed costs (design, planning, materials handling, set-up, etc.) are spread over a small number of units. Capacity utilisation ratios are low and hence economies of scale cannot be attained (Ayres and Miller, 1983).

In mass production, the trade-off works the other way. Dedicated production lines operating at high capacity are used to produce one standard product. However, the lines cannot be altered to produce a different product should the nature of demand change abruptly. This encourages a tendency towards product and technique standardisation which allows production at low unit costs but which can also weaken the competitive position of a firm in the face of changing consumer demand or 'product cycle' shifts to lower cost producers. The best example of this comes from the US automobile industry where post oil price rise demands for more efficient cars caused firms to scrap entire production lines in order to shift from the production of eight cylinder to six cylinder engines.

TABLE 3.6

Capital Cost and Reported Savings in Operating Costs for Selected Flexible Manufacturing Systems

User Sector	Cost (1982 $)	Product volume and part variety	Comparisons with old system
Truck axles	$ 5.6 million	24,000[a] 45[b]	1/4 floor space; set up costs eliminated
Aircraft engines	$ 8.4 million	24,000[a] 9[b]	1/3 floor space; 1/4 labour; 50% number of part holding devices
Tractor components	$18.0 million	50,000[a] 8-12[b]	Cost: $18 million to replace dedicated transfer line at cost of $28 million
Truck components	$ 5.0 million	65,000[a] 5[b]	Cost of FMS the same as dedicated transfer line, with comparable cycle time but less flexibility
Construction equipment	$ 5.0 million	8,000[a] 8[b]	Total transit time through system: old system: 8.5 hours new system: 0.3 hours

Source: adapted from Ayres and Miller (1984)

[a] total number of parts per year machined on system

[b] number of different part types machined on system

The advent of flexible manufacturing systems is changing the technical and economic conditions governing both mass production and batch production methods. In batch production, linking robots to CNC tools either as one unit or as part of a manufacturing cell in a flexible system substantially increases the potential level of capacity utilisation. This facilitates economies of scale but allows the firm to retain multi-product flexibility. In mass production, minimum levels of output to achieve economies of scale can be lowered substantially by creating the possibility of adjusting equipment to produce a different product quickly and easily. Ayres and Miller (1983) cite the example of Massey Ferguson who after choosing to produce transmissions and axles using a large scale dedicated transfer line, opted instead for a flexible manufacturing system that was both less expensive and quicker to install. We have already noted how Japanese automobile manufacturers are able to use flexible systems to produce cars cheaper than the South Koreans who have much lower wage costs. Table 3.6 demonstrates even more graphically the full set of systems gains that arise from flexible manufacturing systems.

As these systems diffuse more widely into sectors where Third World countries might normally have expected to attain a degree of international competitive advantage, it appears that these countries must either introduce the same technology or else permanently confine themselves to markets where this type of competition does not exist. On the other hand, a situation might arise where market conditions in developing countries lead to demands for small batch production. Here flexible manufacturing systems could be justified in terms of private but not social gains.

Impact on skills

Observers who consider whether or not the use of MRIs in developing countries can be justified commonly focus solely on the issue of labour productivity. Since labour costs are usually very low in the Third World, the usual reaction is that the use of MRIs in most developing countries cannot be justified on financial let alone social grounds. However, the above discussion suggests that there may be other grounds for introducing the technology apart from saving labour. This of course is an empirical question in which both social and financial costs and benefits need to be taken into account. However, even where there may be *a priori* grounds for using the technology, the case study literature suggests there are many other factors that come into the equation. One of the most important of these relates to the skill implications of using the technology. Early concerns in the developed countries focussed on the "deskilling' effects of industrial applications. Techniques such as CAD, robots or CNC tools were seen as outright substitutes for skilled workers who would be replaced by far fewer numbers of less skilled (and lower paid) workers. There are two points to note in this regard.

First, the evidence is not clear that deskilling is an inevitable consequence of the introduction of MRIs. Senker (1983) cites research in the UK and West Germany which shows that while British firms do tend to use new technology to deskill the work of craftsmen, West German firms try to use the technology to enhance the skills of their craftsmen. In this case the differences were due entirely to the attitudes of British management towards its skilled workers.

Second, as we noted earlier, deskilling may be much less of an issue in relation to the developing countries where skill shortages are an endemic problem. Such shortages can often prevent firms from expanding output or moving into new product areas where there is a local market presently being filled by imports. To the extent that scarce skills can be replaced by the microprocessor, the use of intelligent machines might be justified in these situations. These were the reasons given by Argentinian and Brazilian users of CAD and CNC technologies as the principal motivation for their use of the technology (Chudnovsky, 1984).

There is of course much more to the skill implications of using MRIs in developing countries than the possibility of saving on labour skills. Apart from operators, the use of MRIs has implications for three broad skill categories which bear directly upon policy concerns in developing countries.

The first category relates to management skills. The selection of the right technique and its efficient introduction and operation depend critically on management capabilities. Managerial inefficiency has been found to be a significant factor impeding the use of MRIs in British industry (Arnold and Senker, 1982; Bessant, 1983). Introducing new technologies puts considerable strain on managerial resources - competent evaluations have to be carried out; considerable reorganisation of the production process may be involved; a good deal of worker education may be required, etc. These pressures obviously intensify as the level of sophistication of the technique being introduced rises. The use of microelectronics technologies should under no circumstances be considered as a panacea for inefficiently managed firms. Given the inherently weak condition of management skills in industry in most developing countries, the management implication of the technology clearly needs very careful consideration when the possibility of its use is being explored.

The second type of skill implication was emphasized in the discussion about machine tools in Section 2. The use of microelectronics in new products has important implications for design skills. New skill mixes are required which combine electronic engineers, computer and software skills, and system design skills as well as the usual complement of conventional skills. Most important is that these skills have to be deployed in a multi-disciplinary setting. Production engineering skills have to be mixed with system design skills to facilitate the introduction of MRIs in the production process. These innovations rarely "fit" existing processes - even when they are off-the-shelf techniques. The availability of production engineers with knowledge of electronics and systems design becomes crucial in this situation. Even in the developed countries many firms have found that they lack these skills and often have to turn to suppliers to help them make the necessary adaptations. In developing countries, system suppliers are unlikely to maintain the full range of support facilities normally offered in the developed countries. This means that users will have access to these skills either by developing them in-house or by having them locally available. Once again this points to an obvious but important area where explicit steps will have to be taken to ensure that these skills are available in developing countries.

Finally, maintenance skills are also important, and many users and suppliers in the developed countries repeatedly cite the lack of these skills as a major deterrant to the use of MRIs in industry. Maintenance personnel tend to be poorly trained, if they are present at all, in developing countries. Yet MRIs tend to be more complicated than conventional techniques, not only due to the electronics involved but because of the other types of technologies which are present as well - e.g. servo-mechanisms in CNC tools. While suppliers are constantly improving their diagnostics to overcome this, maintenance requirements unquestionably increase when MRIs are present. It is inevitable that all developing countries will, in future, import greater quantities of equipment which utilize microelectronics. It is therefore essential that steps be taken to ensure that an adequate supply of properly trained maintenance personnel is available to service the equipment.

Section 4: Other Implications of Microelectronics

Sections 2 and 3 discussed in detail the most immediate and in our opinion most important implications of microelectronics for policy in developing countries. However there are other elements and two of these are mentioned briefly in this section.

Microelectronics and the nature of work

All technology is a product of the social context within which it is developed and diffused, and in this regard microelectronics is no different from any other technology. The enormous resources poured into the development of what are arguably socially useless consumer electronics products are a case in point. One could of course make a similar but broader case about the whole range of information and automation technologies brought into being by microelectronics. These techniques are hardly required to satisfy basic human needs but are developed in response to induced demand and the conditions of production that prevail in market economies. From this perspective, automation technology, like earlier forms of mechanization and the division of labour, can be seen as part of the continuing efforts of management to use technology to make the most efficient use of human resources.

The issue of control is central to the impact of microelectronics on the nature of work. Given all the evidence, it goes almost without saying that microelectronics very substantially enlarges the scope for substituting machines for labour - a process long characteristic of technical change in market economies. Apart from the issue of outright labour displacement which we discuss next, the evidence suggests that automation technology tends to have a number of effects on the relations of production, all of which have been long recognised as the seemingly irreversible result of the predominance of capital over labour in market economies.

First, jobs within traditional manufacturing industry do tend to be deskilled even when the craftsman or skilled person is retained to operate the machine. In Marxist terms, jobs are fragmented and in the process, the conception of work is separated from its execution. This results in loss of job satisfaction and reduced labour power. The literature contains many examples of this. Shaiken (1980), for instance, points out that the greater flexibility of CNC tools and FMS erodes the basis for craft skills in manufacture and gives one graphic quote from a machinist assigned to a CNC machine tool to illustrate the point:

> "I've worked at this trade for seventeen years. The knowledge is still in my head, the skill is still in my hands, but there is no use for either one now. I go home and feel frustrated - like I haven't done anything." (Shaiken, 1980, p.29)

Second, automation technologies tend to introduce machine pacing into craftskills which had previously been labour-paced. Kaplinsky (1984) cites the example of a CAD operator who formerly had physically drawn for about 30 per cent of his day but now had to sit in front of the CAD screen all day. His work rate was therefore much more intense (including night shifts to allow maximum capacity utilization) and paced by "user-friendly" promptings from the system. Here, too, deskilling was evident as well, since each operator produced identical drawings and letterings with the CAD system and as a result the individual's pride in his skill was eliminated. Similar examples could be cited in many other situations where automation technologies have been introduced.

Third, the deskilling effects of automation technologies may also reduce the bargaining strength previously enjoyed by skilled workers. For example, in the clothing industry, cutters (who are all men) were traditionally the highest skill group and the most militant - if cutters stopped work, production halted. One large UK clothing firm introduced CAD and automated cutting precisely in order to break the industrial power held by the firms' cutters.

Finally, skill polarization also tends to occur. A new set of electronics and software based skilled jobs are created on the one hand, and on the other, a set of less skilled machine minding jobs. Together these are often fewer in number than the craftsmen jobs which are lost. This leads to a restructuring of work relations and job responsibilities within the firm which overall might tend to increase management control. This process is further reinforced by the real time monitoring capability of the technology.

The precise way in which this set of labour effects work themselves out in practice obviously varies enormously. Indeed conditions within new "high tech" firms can differ substantially from those in established industries where management and labour attitudes have been conditioned by the operating conditions of work which characterised the old production paradigm. Much depends on the spirit in which labour and management approach the task of negotiating new technology agreements. These have to take account of changing job definitions, alterations to shift arrangements, less favourable working conditions (eg eye strain from the use of VDUs) and changes in host of other areas. Though experience in handling negotiations over the introduction of new technology is being accumulated by both management and labour, it is clear that a long learning process will be necessary in order to cope with the increasingly complex demands imposed by more advanced forms of automated manufacturing and the general rise in the information intensity of production.

The negative impacts described above are not necessarily inevitable and inherent in the technology. The example of West German firms using CNC tools to enhance the skills of their craftsmen is a case in point and there are undoubtedly many others. Their importance must not be lost sight of particularly since they often arise because labour and management have explicity adopted a collective concern to minimize the negative effects of introducing automation technologies. Given the social costs and social tensions which arise where such an approach is not adopted, it would appear that the choice of how the technology is introduced and used within the firm is far too important an issue to be left solely in the hands of one group. This is particularly true when, as Rosenbrock (1984) and others have argued, there may be ways to achieve the same economic gains without such high social costs. Only labour and management working collectively will be able to find such solutions.

Employment implications at the firm, sectoral and national level

The debate over the employment effects of technical change has a long history dating back at least to Ricardo's famous appendix "On Machinery" which first advanced the idea that the use of labour saving machinery could result in short-term unemployment. The issue was of major concern in the 1930s, 1950s and 1960s, and now seems to dominate discussion. Given that background and the controversy surrounding the issue, one either needs to devote a book to the topic or mention it only briefly. In this report, we have opted for the latter course both because of the space constraint and because we do not see microelectronics related employment issues as being among the most crucial policy problems confronting Third World policymakers in the short to medium term.

Given these constraints there are nevertheless a few salient points which might be usefuly mentioned here. The first is that the employment effects of microelectronics are most readily apparent at the level of the firm. This is the case whether one is talking about labour displacement or job creation. Examples of both effects drawn from studies in the UK are given in Table 3.7 and 3.8. The amount of evidence which can be cited to support either case is of course directly related to the perspective of the analyst - protagonists from either camp are notably reticent about dredging up evidence to support the opposition's position!

TABLE 3.7

Selected Example of Labour Displacement due to Introduction of MRI's in UK

Total employed	Application	Jobs lost
400	CNC machinery replacing existing machine tools	45 (60% in affected area)
120	Moulding machinery in foundry	24 (100% on 2 shifts)
800	Loom controls now replaced by microprocessors in textile firm making woven products	Up to 100 (60% in affected area)
28	CNC machines (lathe/chucker) replacing conventional on a 1 for 3 basis	4-8
3,000	Joint testing machinery in assembly	10 (50% in affected area)
180	Plastics processor; installing complete new line	- (40% overall)
700	Die casting machinery with automatic take-out	15
1,000	Chemical firm installing new automated process with centralised control	12 (40% in affected area)

Source: Bessant (1982)

The second point is that while such studies are useful in illustrating the types of jobs created or lost, they tell us very little about the net employment effects at the sectoral or national level. This is so for two reasons. First the operation of the so-called "compensation" mechanism - whereby jobs lost due to technical change in one location are balanced by jobs created in another location - is extremely complicated and not at all transparent in a modern industrial economy with its complex levels of inter-sectoral flows, multi-layered, non-electronic related technical change processes and other macro relationships. The second factor is that attempts to discuss the ways in which these indicators are currently moving are frustratingly obscured by the variable length and depth of fluctuations of the business cycle. Most earlier well publicised estimates of job losses that would arise from microelectronics applications missed these two points entirely (with their predictions being made on the basis of simple extrapolations) and hence should be accorded little attention. (See Jenkins and Sherman, 1979 and Hines and Searle 1979, for examples, and Cooper and Clark, 1982 for a critique.)

TABLE 3.8

Selected Examples of Job Creation due to Sales of Microelectronics Based Products in UK

Products	Annual Sales	Number of Jobs Created
Software/hardware package for computing on farm	500,000 - 1981 1,000,000 - 1982	20 (direct) 10 (indirect)
Cobol compilers and software development tools	100-150% growth/year 12m in 1981; exports 60-70%	60 (direct) ? (indirect)
Importer of electronic components	Average £500,000 last 3 years	17 (direct) 6-10 (indirect)
Range of specialist soft/hardware products for industrial users	800,000 - 1979 at takeover	40 (direct) 20 (indirect)
Flue gas monitoring devices	£3m in 1981, growth of 50% for mp products since introduction Now accounts for 50% of sales	45 in 1978 75 in 1982 (direct) 75 in " (indirect)
Electronic cash registers	No details but 7,000 imported/assembled units sold in 1981; 14,000 expected for 1985	Number employed 1975 - 1,600 down to less than 300 in 1981; only 45 on assembly activities
Computer services to oil well industry - data logging equipment	Not yet breaking even but estimates as high as £10m by end next year	55

Source: Hoffman (1982)

Clearly, given the present scale and structural causes of unemployment in the OECD, the compensation mechanism appears not to be working at all well. This is an extremely serious problem that needs a great deal more attention from governments than has so far occurred. However it is important to note that at least in the early years of the recent recession, microelectronics related technical change was *not* the cause of the large majority of job losses. This is borne out by Table 3.9 which shows that in the EEC, unemployment was rising at the same time as aggregate labour productivity was falling. If the widespread use of microelectronics had been responsible for job losses, then presumably labour productivity would have been rising.

The third point to note is that despite uncertainties about general trends, it is indisputable that employment levels in certain sectors have been affected by the use of microelectronics technology in either products or processes (see, for instance, ETUI, 1980 for a comprehensive review). In general, the industry-wide employment consequences of the technology seem to be much more pronounced in sectors which are either closely related to the electronics industry or whose activities have a high information content. Considering first the electronics complex and taking the UK as an example, (labour productivity grew at an annual average of 6.8 per cent between 1974 and 1981 and shows little sign of slowing down (Soete, 1983). Table 3.10 gives a more disaggregated breakdown of employment and output trends in different subsectors. This shows there are significant differences between sub-sectors, with computers and electronic capital goods being the only ones to

TABLE 3.9

Unemployment and Labour Productivity Growth in Industry for Selected EEC countries, 1976-1981

Year	Belgium		Denmark		Germany(FR)		France		Italy		Netherlands		UK	
	P	E	P	E	P	E	P	E	P	E	P	E	P	E
1976	13.0	6.7	7.5	4.7	9.2	4.1	8.6	4.3	12.4	5.6	12.0	4.3	6.8	5.3
1978	5.8	8.4	3.1	6.5	1.8	3.9	4.0	5.2	2.8	7.1	3.6	4.1	1.7	5.7
1981	3.0	10.6	1.5	8.0	2.4	4.1	1.8	7.1	2.9	8.8	4.1	6.3	2.0	9.4

Source: EEC - European Economy, March 1981; and EEC short term indicators (April 1981)

P = annual productivity growth

E = unemployed as percentage of civilian labour force

TABLE 3.10

Gross Output and Employment in the UK Electronics Industries (by 1968 MLH Sector and in 1975 Prices) (UK £ millions) (thousands)

Year	Electronic Components MLH 364		Electronic Consumer Goods MLH 365(2)		Electronic Computers MLH 366		Electronic Capital Goods MLH 367	
	output	E	output	E	output	E	output	E
1970	703	132	293	44	349	51	878	96
1971	699	128	369	48	338	50	817	94
1972	809	127	517	61	322	50	781	80
1973	977	136	495	69	415	46	783	80
1974	1024	153	584	63.5	571	44.5	820	86.5
1975	783	128	495	55	554	43	853	89
1976	830	124	460	50	571	44	887	90
1977	947	129	445	52	676	43	972	91
1978	1033	128	504	50	892	46	1006	94
1979	1096	(128)	519	(45)	1319	(49)	1049	(95)
1980	1175	(121)	494	(43)	1446	(44)	1066	(101)
1981	1127	111	578	24.5	1390	61	1058	110
1982	1206	108.2	613	22.6	1629	58.9	1015	108
Average Annual Output Growth Rate (1970-82)*	4.5		6.2		12.8		1.2	

Source: adapted from Soete and Dosi (1983).

* provisional

display employment growth in the wake of extremely rapid output growth. Not all of the observed productivity growth is necessarily due to technical change (since scale economies are at work and there may be some short-term labour hoarding), but product and process innovations are almost certainly responsible for the majority (Soete and Dosi, 1983). Similar trends would almost certainly be found in the electronics complex (including telecommunications) other countries, with the US and Japan perhaps showing rather stronger gains in employment as a result of the exceptional output growth documented in Chapter 1.

Employment in a number of other sectors has also been affected by the diffusion of MRIs. The printing and publishing industries, for instance, experienced a wave of radical technical changes in the 1970s that resulted in a net fall in employment (and serious conflicts with organised labour). In the UK some 17,000 jobs disappeared during the 1970s due to process innovations such as computerised type setting. Similar trends were reported in West Germany, where over the 1975-1980 period, employment declined by 21 per cent while productivity rose by 43 per cent (Heywood, 1982).

Perhaps the sector which has experienced the greatest impact so far in terms of employment has been services and office activities, with the effects being particularly severe on women who form the majority of workers in that sector. There are a number of case studies which have tried to document the employment effects of office automation (see Werneke, 1983 for a review). Jobs are unquestionably disappearing in the service sector as a result of the increasingly intensive use of the type of technology documented in Chapter 2. In some cases workers actually lose their jobs and in others they are shifted to different jobs or re-trained within the firm.(13) The net overall effect so far appears to be a substantial slowdown in the rate of creation of new jobs in the service sector rather than an actual reduction in its employment. This is clearly of major concern since traditionally the service sector has been expected to absorb labour displaced from manufacturing. Its capacity to do this is being reduced, and an authoritative review carried out by the OECD expects the pace of net job losses to increase substantially in the medium term (Barras, 1984).

Turning to other sectors there is a strong assumption in the literature that employment in engineering would be affected in a major way by microelectronics. This is worrying since this sector is of major importance to the OECD economies. Indeed many of the examples which have been cited earlier come from this sector and there is little question that the diffusion of microelectronics techology is affecting employment in engineering. But recent reviews by OECD and others have concluded that so far, particularly in the mature industries, the net employment displacement effect has been moderate in the sector, and certainly far below earlier expectations (Wilson, 1984; Senker, 1983). Employment has obviously declined, as shown by Table 3.11 for the U.K. but this is due to both structural change and the recent recession. The uneven diffusion of microelectronics technology has restricted major employment effects to a relatively few segments of the sector. As to the future, there is a feeling in the literature that as the pace of diffusion continues to increase, job losses will rise. Whether or not the compensation mechanism will operate sufficiently strongly to absorb the job losses either within the sector or elsewhere in the economy is impossible to predict. It is clearly not now operating effectively in most countries because of the severity of the recent recession and the large degree of structural (as opposed to demand deficient unemployment) that exists. This is true not only for the engineering sector but for many others as well.

TABLE 3.11

Employment in Engineering Industries in the UK, 1961-1981 (thousands employed)

Industry	1961	1971	1981
Mechanical engineering	1,043 [17.5]	1,063 [1.9]	803 [-24.5]
Instrument engineering	161 [18.4]	168 [4.5]	138 [-17.9]
Electrical engineering	748 [44.3]	818 [9.3]	698 [-14.7]
Shipbuilding and marine engineering	258 [-12.1]	194 [-24.8]	144 [-25.8]
Motor vehicles	438 [27.6]	534 [21.8]	371 [-30.5]
Aerospace	295 [52.3]	218 [-26.2]	194 [-11.1]
Other vehicles	154 [-14.0]	67 [-56.8]	55 [-17.4]
Metal goods n.e.s.	579 [11.0]	593 [2.5]	467 [-21.1]
All engineering	3,677 [19.6]	3,654 [-0.6]	2,870 [-21.5]

Source: Wilson (1984)

[ ] - % growth over previous decade

What impact then will microelectronics have on employment in the future? The eventual outcome will depend on two sets of interrelated factors. The first is the effect of this technology on international competitiveness. If an economy fails to adopt the technology as quickly or as efficiently as its competitors, then jobs lost as a result will obviously be net losses to the country concerned - and gains to its competitors. We are back to the dilemma posed at the beginning of the chapter - firms (and the economy as a whole) are much more likely to experience loss of market share and therefore of employment if they do not utilize the new technology than if they do. But what if they do adopt the technology? This is where the second factor comes in; it is also the point at which the economic reasoning of many observers breaks down when they argue that the widespread diffusion of the new technology can only lead to net job loss because of increased labour productivity. This will be true only if overall output is expanding more slowly than that of labour productivity. If, however, the reverse is true, then employment should expand.

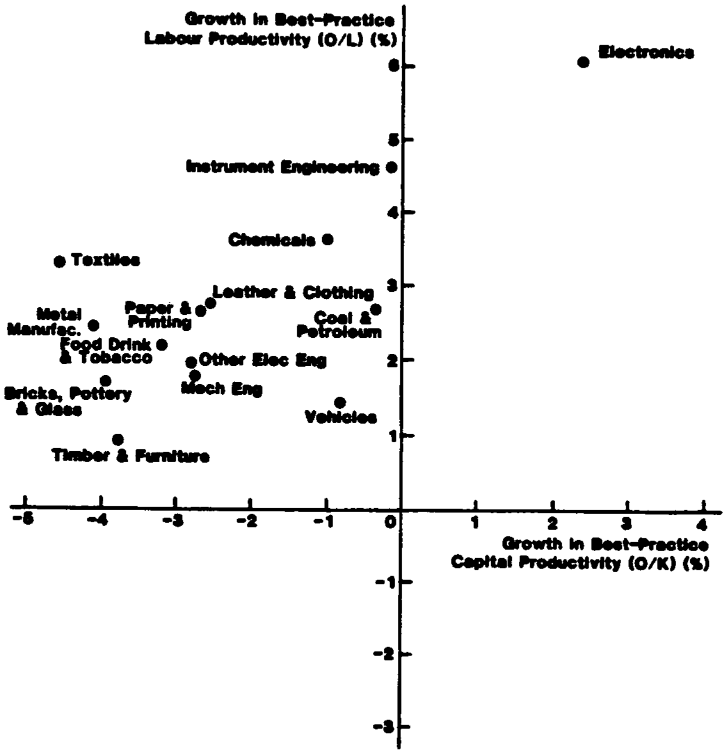
But can the diffusion of microelectronics actually have this effect? The answer depends in large part on the effects of the technology on *capital* as well as on labour productivity. If capital productivity rises (i.e. more output can be produced per unit of capital), then two things should happen - profits should increase and relative prices for the products or services being produced should decline. This should lead to a growth in demand for these products, investment should rise (supported by increased profits) and therefore more jobs should be created. We pointed out in Section 3 that although *a priori* arguments are made that microelectronics is indeed capital saving, there is as yet little evidence on this at the level of the firm or industry. Flexible manufacturing systems exhibit tendencies towards capital savings but as yet these are too limited to have any discernible micro effects.

However recent research at the Science Policy Research Unit of the University of Sussex has generated evidence that at least within the electronics sectors of the UK, microelectronics has indeed begun to exhibit capital saving effects (see Soete and Dosi, 1983; Patel and Soete, 1984). This is demonstrated in Figure 3.2 which charts the post-war growth in best-practice capital and labour productivity for major industrial sectors in the UK between 1954 and 1980. The location of all but one of the observations in the upper left hand quadrant confirms the well-known tendency towards labour-saving technical change. Electronics is the only sector which has experienced simultaneous growth in best practice labour and capital productivity. The reason comes out more clearly from Figure 3.3 which disaggregates the trend in best practice labour and capital productivity for the major electronic sub-sectors between 1959 and 1980. The thirty-fold growth in the labour and capital productivity of producing computers is most striking. It is due in large part to the price effects of that industry's intensive use of electronic components, whose sharp downward trend in unit costs in turn contributed to the enormous expansion in demand that has occurred for computers (as documented in Chapter 1).

Though the above capital and labour saving effects of microelectronics have so far manifested themselves only in the computer industry, one can easily postulate the ultimately favourable effects on output growth and therefore employment growth as the technology diffuses throughout the economy. Demand and hence output will grow for products of the electronics complex. This is already happening for electronic capital goods. Due to the decline in relative prices of labour and existing capital demand will then grow for the consequently relatively cheaper manufactures and services produced with electronics-intensive automation technologies (Patel and Soete, 1984). This in turn should have a favourable impact on investment and on employment not only nationally but also internationally. Precisely how any one economy will fare relative to others will then depend on the rate at which the technology diffuses and the relative effectiveness of its use in product and process applications.

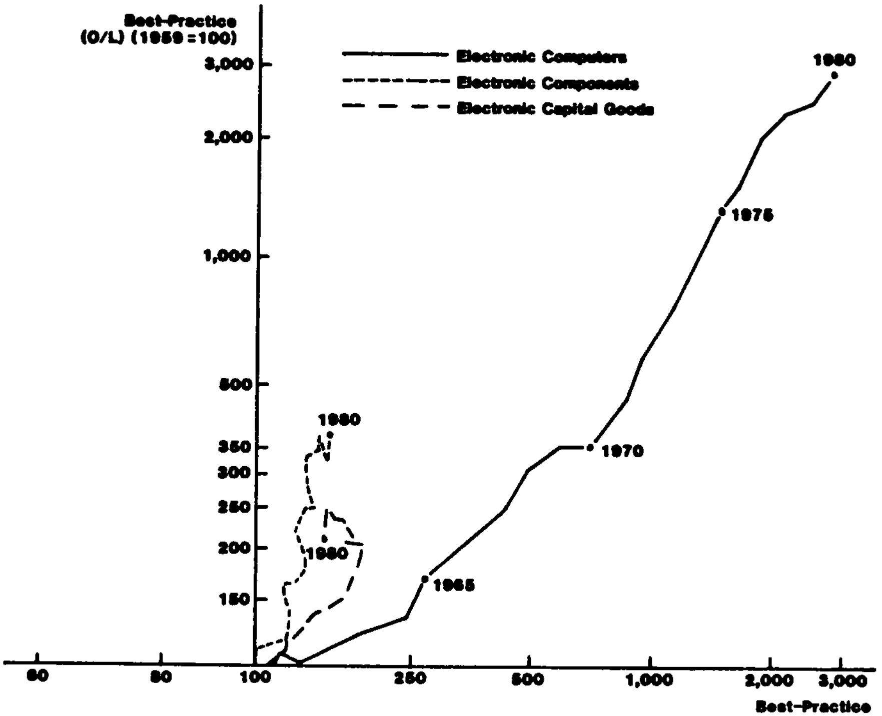
We must stress that this reasoning is highly speculative since we are relying on evidence (which could itself be criticised) from only one sector in only one economy, both of which may be atypical. However, the recent performance of the UK economy does bear a strong resemblance to a number of other European economies which have experienced a slowdown in investment, tendencies towards labour saving technical change, and a rise in structural and (arguably) demand deficient unemployment (Soete and Freeman, 1984). Consequently the arguments seem plausible enough to generalise. But like all economic analysis, this reasoning obscures many factors. For one thing we are talking about a process that will take a relatively long time to work. In the interim there is little doubt that there will be employment displacement, particularly in those sectors where the straightforward substitution of capital for labour will not be fully compensated by output growth. Another much more important point is that for the mechanism to work at all, it has to work on a large enough scale to affect the whole economy and not just a few sectors; and for this to happen a great many "facilitating" factors have to be present. It is enormously difficult to create these conditions when so many countervailing forces are at work. These are issues we turn to in the final section of this chapter.

Figure 3.2: Post-war Growth in Best-practice Labour and Capital Productivity in the UK Manufacturing Sectors (1954 - 1980)



Source: Soete and Dosi, 1984

Figure 3.3: Trends in Labour and Capital Best-practice Productivity: Electronic Subsectors (1959-80, 1959 = 100)



Source: Soete and Dosi, 1983

Section 5: Need for Social and Institutional Change

With the above background we can now consider some broader concerns about the overall impact of microelectronics on society. This is difficult to do briefly but it is essential if one is to grasp the full significance of the phenomena we have been examining. In Chapter 1, we argued that microelectronics had a set of characteristics which qualified it as a "heartland" technology applicable throughout the economy and capable of stimulating successive rounds of technical change. Evidence on this was presented and in the last section we highlighted the economic mechanism by which the diffusion of the technology could stimulate the expansion of output and employment on an economy-wide scale.

The economic rationale underlying this interpretation is essentially based on a supply-side interpretation of the role of innovation and technical change in market economies. It is a highly controversial view that departs from both Keynesian orthodoxy and monetarist theories, and stems from the arguments originally put forward by Joseph Schumpeter. Schumpeter believed that the long term performance of market economies was driven by the wave-like behaviour of the innovation/investment process associated with the emergence of major technological advances. Freeman and Soete (1984) point out three essential aspects of Schumpeter's argument. The first is that these innovations do not emerge in an ad hoc fashion but concentrate in key sectors and therefore give rise to problems of structural adjustment between sectors. Second, the process of diffusion of these innovations is a cyclical phenomenon that starts slowly but moves into a rapid growth phase as a large number of imitators perceive profitable investment opportunities associated with the new technology and "swarm" to take advantage of these by developing new products and processes (the well known 'S' curve effect). Once begun, this swarming process has extremely powerful multplier 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.

Finally, over the course of decades, the swarming process inevitably slows as increased competition sets in and erodes the profit margin of the innovators. As this occurs, investment and innovative behaviour shift from an expansionary mode involving new product and capacity creation, towards rationalization and cost-reducing innovations - which because of standardization and scale economies have much less potential to generate jobs. As a result, the economy's growth first slows, then stops and ultimately enters into decline.

The historical evidence suggests that this process of swarming-induced multiplier and retardation effects accompanied the earlier diffusion of major innovations (associated with periods of expansion and decline in market economies) such as steampower, steel, railroads, internal combustion engines, chemicals and, as we indicated in Chapter 1, electricity and electronics. The evidence presented earlier on the effects of microelectronics related innovations in computers, telecommunications, and information technology strongly suggests that these exhibit the same potential to stimulate the expansion of the whole economy.

Despite this potential, the problem for policy is that there is no guarantee that the mere existence of a technology like microelectronics will on its own be sufficient to trigger the economy-wide diffusion process which must occur for expansion to begin. Creating the right economic climate for innovation and diffusion to begin on a global level cannot be done by simply relying on policies to stimulate demand or remove labour market rigidities and improve the industrial relations environment. These are necessary but largely passive policies that will not provide the sufficiently strong impulse needed to "lift" the economic system onto a higher path of economic growth (Soete and Freeman, 1984). What is necessary is 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. These would go far beyond even the most ambitious programmes in place today and indeed would run counter to prevailing economic orthodoxy.

The problems do not stop here however, for quite apart from the need to get the right economic environment, there is also need for a fundemental change in the social and institutional relations which govern the actions and interactions of groups both within the economy and at the international level. As Perez (1985) points out, a social and institutional revolution is required to allow the technological revolution to proceed:

> "The transition to a new techno-economic regime cannot proceed smoothly, not only because it implies massive transformation - and much destruction - of existing plant, but mainly because the prevailing pattern of social behaviour and the existing institutional structure were shaped around the requirements and possibilities created by the previous paradigm. That is why, as the potential of the old paradigm is exhausted, previously successful regulating or stimulating policies do not work. In turn, the relative inertia of the socio-institutional framework becomes an insurmountable obstacle for the full deployment of the new paradigm. Worse still, the very diffusion of the new technologies, as far as conditions allow, is itself an aggravating factor because the new investment pattern disrupts the social fabric and creates unexpected cross-currents and counter trends in all markets. Under these conditions, recessions and depressions can be seen as the syndrome of a serious "mismatch" between the socio-institutional framework and the new dynamics in the techno-economic sphere. The crisis is the emergency signal calling for a redefinition of the general mode of growth".
> (Perez 1985, pp.11-12.)

Hence a long and thoroughgoing process of social adaptation to the demands of the new microelectronics-based technological paradigm will be required. As both Perez (1985) and Soete and Freeman (1984) urge, it is crucial not to misjudge the vast scope of change which would be necessary in all spheres of national and international social and institutional interactions. These would need to occur, for instance, in the:

regulations of various markets governing the international and national movement of products, capital and labour;

organisation of the banking and credit system;

forms of labour organization and the legal framework in which they operate;

education system and the form of training and skills in imports; attitudes of management and labour and the pattern of industrial relations and worker participation; and

conceptual frameworks of economists, accountants and governments, and in social, political and legislative priorities.

This scale of change cannot be achieved without cost or in the absence of bold attempts at institutional innovation similar to those that accompanied the upswing after World War II.(14) These ultimately provided a stable environment for the subsequent upswing. But it must be noted that this institutional transformation only took place after the world economy had experienced years of depression and a devasting global war.

It is not possible here to give a full presentation of the still controversial arguments sketched above with all the attendant qualifications and theoretical and empirical justifications. But hopefully the above gives some idea of the scale and scope of the phenomena we are presently witnessing - and the highly uncertain nature of the outcome.

At its roots the view given above may be optimistic - at least as far as the developed countries are concerned. But what of the implications of microelectronics for the Third World and for the broad policy approaches that need to be adopted. One can only speculate here about two possible scenarios. The first is pessimistic and rests on the enormous gulf between the levels of economic, technological, political and social developments in the North and in the South. Developed countries can arguably be seen to be capable of adjusting in time to the rigorous demands of the information revolution (though not without cost to some groups) and thereby embarking on a new and accelerating path of expansion. The constraints under which most Third World societies operate, however, suggest that they could be left behind - with the poorer groups who make up most of the population in these societies suffering a dismal fate.

The second scenario is more optimistic but still qualified. The source of the optimism lies partly in a belief in the resilience and innovativeness of the Third World. It also 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. We would argue that developing countries should continue to seek to reform the international insitutional systems, particularly those associated with technology transfer. To achieve credibility in such an endeavour, they must themselves undertake fundamental internal reforms. It is uncertain whether these countries will be able and willing to pursue these steps. But 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. If the initiative is not seized soon, then it is arguable that a great opportunity to create more favourable prospects for their future development will have been lost.

To the extent that such a response would also require the developing countries to embrace the new technology wholeheartedly raises a host of other issues of which we only mention two here. The first is that even if they do choose to pursue path, the ability of different countries actually to succeed will obviously vary widely. Second, and much more important, is the fact that following such a path constitutes a fundamental normative challenge to the very nature of development in the Third World. It is not possible or indeed even ethical for an outside observer to suggest which path should be chosen.

Footnotes to Chapter 3

(1) See OECD 1980 and Soete 1981b for discussion of the various explanations of the productivity slow down.

(2) UNIDO's famous Lima Declaration in 1975 argued that the Third World should account for 25 per cent of world MVA by the year 2000 and pushed strongly for countries to pursue export-oriented policies. In the World Bank Report "Accelerated Development in Sub-Saharan Africa: An Agenda for Action", the stimulation of agricultural production and expansion of manufactured exports are seen as the two key strategies to be pursued in the 1980s.

(3) UNCTAD has identified over 25,000 different tariff and non-tariff barriers imposed by developed countries and largely aimed at imports from developing countries. See also Commonwealth Secretariat, 1982.

(4) Larger firms in the industry spend between $5million and $7million per annum on R&D while NIC firms spend only a fraction of this. (Chudnovsky et al, 1983.)

(5) Minimum scale economies for international products tend to be between 500-700; but demand in the NICs rarely goes above 80-100 units. (Chudnovsky et al, 1983; Hoffman and Rush, 1986.)

(6) Examples come from men's shirts, children's and ladies' outerwear, hosiery, boots and jeans.

(7) Countries such as Sri Lanka, Malaysia, Indonesia and Mauritius are all operating far below capacity because of increasingly restrictive barriers in the main importing countries.

(8) Large TNC shirt firms expect that the use of automation will alllow them to begin moving their offshore production back to the domestic market within five years. Since in the case of the US, imports of men's shirts came to $1.7 billion in 1983, far smaller producers will probably be able to take advantage of the techniques; this could be quite a serious threat to Third World exporters.

(9) See Hoffman and Rush, 1986 for an analysis.

(10) The only major recent entry into state-of-the-art IC production has been INMOS in the UK, which at that time was publicly financed.

(11) For instance, four bit microprocessors represented 100 per cent of the world microprocessor market in 1972, 23 per cent in 1980, and only 6 per cent in 1985. Firms such as Fairchild, one of the leading chip makers of the 1970s, has floundered badly in recent times due to a lack of product innovation.

(12) Cheong and Lim (1981), for instance, cite a survey of 60 electronics firms operating in Malaysia, to claim that foreign subsidiaries have transferred very little technology.

(13) Rada (1983) cites the example of Citibank whose extensive introduction of computerization and office technology displaced jobs but where all the workers were transferred to other jobs within the firm.

(14) These range from the use of Keynesian forms of intervention to guide the economy, the Bretton Woods agreements, and unemployment insurance, to the establishment of GATT.

CHAPTER 4

THE PRESENT STATUS OF POLICY TOWARDS MICROELECTRONICS

This chapter gives a brief overview of current policy approaches towards microelectronics which have been adopted by some Commonwealth countries. Unfortunately, apart from the developed member countries and one or two developing member countries such as India and Singapore, there is little published information on government policy in this area and virtually none on the impact of these policies.

No country in the world has yet developed a comprehensive policy framework which deals with all aspects of the development and use of microelectronics technology, either in relation to the short run or the long term perspective suggested in the final section of Chapter 3. But several developed countries do have a wide range of policy measures in place - both general and specific - which are slowly evolving into an integrated approach. France and Japan are probably furthest advanced in this regard. Among the developing countries most of the more coherent policy efforts, which are few anyway, concentrate on the development of the electronics sector and to a lesser extent on the use of computers and information sector. Apart from Singapore and Malaysia, and to a lesser extent India, most of the developing countries in the Commonwealth have not devised an explicit and comprehensive policy for the industrial use of the technology - either these aspects are covered by existing, more general, policies or else there is simply no policy at all.

To facilitate the discussion the countries of the Commonwealth can be disaggregated into four groups. The first consists of the advanced industrial economies. In these countries policies or strategies have been adopted on the development of the electronics complex, the development and diffusion of microelectronics applications in industry, and in relation to broader issues such as education, training, user awareness and the development of the information infrastructure of the country. In Section 2, we shall highlight the policies of the United Kingdom under this category because it has gone furthest towards policy formulation and implementation.

The second group comprises the primarily export-oriented economies of Asia (Singapore, Malaysia, and Hong Kong) which have a deep involvement in the export of electronics products and whose experience may therefore be able to offer some useful guidelines to other countries thinking of following the same path. Within this group of countries, we shall focus on Singapore in Section 3 and in particular on its strategies in relation to the development of an export-oriented software industry.

The third group of countries are the larger economies: India, Bangladesh and Nigeria. These countries have a potentially large domestic market for electronics products and need to further develop their industrial capabilities. Of the group, India is the most advanced in terms of its approach both to the electronics sector and to industrial technology policy. We shall highlight India's electronics sector policies in Section 4.

The fourth and by far the largest group consists of the numerous, small, more agriculturally oriented economies in Africa and the Caribbean. For the most part, these countries have a poorly developed electronics industry and an equally underdeveloped industrial sector. None have gone very far in formulating policies towards electronics and indeed most lack any form of science and technology policy, as is the case with some of the countries in the other categories. Nevertheless, many of these countries have taken some, albeit fairly small and isolated, steps towards developing policies dealing with the introduction and use of computers. To the extent that information is available, their experiences will be highlighted in Section 5.

Innovation in developed countries: some background comments

Before describing UK Government policies towards microelectronics it may be useful first to make a few general points about the experience of developed country governments in providing direct support for innovative activities. Increasingly during the 1970s there was a growing awareness of the importance of innovation and technical change, both as a motor of economic growth and as a source of international competitiveness. Many analysts have argued that there is now a clearly defined need for these countries to commit more resources to stimulate technical change and diffusion (see Freeman, 1979 and OECD, 1980 as good examples). These measures are seen as being able both to help economies break out of recession and, perhaps more importantly from the point of view of individual governments, as a key element in maintaining international competitiveness and reaping the resultant benefits in terms of employment generation and balance of payments contribution.

In laying stress upon the link between innovation, economic growth and international competitiveness, we are aware of the obvious limitation in implying that there are single factor explanations for any development in any economy. The factors making for industrial "success" within the North are many and varied - culture, educational levels, government policies, entrepreneurial attitudes, the organisation of production, etc. There is likely to be no single key to success or cause of failure. Innovation, or lack of it, is only one of these, albeit, as we have tried to argue, an increasingly important factor.

A very wide spectrum of industrial policies have been tried by governments in developed countries to try to stimulate their economies to make the necessary adjustments to the economic conditions which have emerged over the last decade. Measures specifically concerned with innovation - themselves a broad category - are really only one subset of this larger group. The relative importance that these governments have given to innovation policies has varied widely since the war - even given the dominance of the "technology catching up" mentality mentioned earlier. This suggests that despite the evidence on the relationship between R&D and innovation and economic performance, there is a real danger in assuming that government innovation policies of the last decade have had the effects intended by their drafters, and were in some sense more important than other industrial policies. Difficulty in equating the use of a particular policy with a specific identifiable outcome is a problem which plagues the evaluation (and hence design) not only of innovation policies but of all industrial adjustment policies. Recent analyses of adjustment policies (including support for innovation) have found it fiendishly difficult to reach any generally applicable conclusions on the impact of these policies (de Bandt, 1981; Renshaw, 1981).

Unfortunately, there is little empirical guidance on whether, in any objective sense, more intervention has been better than less intervention. For instance, the Government of the Federal Republic of Germany, one of Europe's most successful economies, is notable for its generally limited desire to intervene. When this does occur it usually takes place with a view to facilitating rather than opposing the working of market forces. France, on the other hand, which is also a "successful" European country, has adopted a much more centralised approach that has strong "planning" elements, particularly in relation to influencing conditions and activities within major sectors and companies. Other countries in Europe combine different sets of interventionist philosophies and policy packages with both good and bad economic performances. The United Kingdom has the dubious distinction of having a free market-oriented government and one of the most extensive degrees of state involvement in Europe, together with what is arguably one of the weakest economies of the developed countries.

All of this uncertainty has not however prevented the developed countries from seeking to provide a considerable degree of support to the electronics complex. Growing awareness of the central role of microelectronics has prompted these countries to focus their intervention efforts increasingly in this area: and indeed in sharp contrast to the more general experience, it does appear that government intervention has been particularly important in stimulating the development of electronics industries in some countries. The presence or absence of intervention has been directly linked to the relative degrees of success or failure of the industry in the OECD countries (Dosi, 1981). The US government, through its military and space programmes, became heavily involved in financing research and in semi-conductor procurement, and thereby deeply affected both the supply and demand characteristics of the semi-conductor industry. Particularly in the early stages of the industry, these programmes were decisive in determining the direction of technical change, in allowing the private sector to be assured of the planned expansion of demand necessary to achieve scale economies, and in stimulating a vast accumulation of knowledge and expertise in the private sector. All of these elements, plus the normal workings of a highly competitive market, helped give US industry a secure base for its early dominance and for the technological leadership it still enjoys in major product areas.

Government intervention in Japan was as extensive as in the US but followed a very different pattern since there was no involvement of the military in direct support for the electronics industry. The policies of MITI, the principal government agency involved, can be seen to be directly responsible for creating the conditions which have allowed Japanese firms to close the post-war technological "gap" with the US and to rapidly increase their share of the world market for various electronic devices. The government's industrial trade policies concentrated on setting technological targets, providing support for R&D, regulating foreign investment, closely monitoring the use of licensed technology to ensure diffusion, and exercising import controls. Moreover, MITI has continually exhibited a impressive capacity to collaborate with the private sector and to integrate their aims with those of the state. This climate allowed the private sector to pursue a well planned campaign to achieve technological parity plus aggressive marketing to maximise market penetration (Dosi, 1981; OECD, 1980).

In the case of Europe, the history of government intervention differs significantly from both the US and Japan. Here military involvement was very much lower and government intervention took place, until recently, on a less comprehensive scale and in a more ad hoc fashion. There were examples of extensive government support for R&D in particular parts of the industry in the 1960s and early 1970s (such as computers in the UK) but these rarely focussed on the semi-conductor sector. Nor were they at a high enough level or sustained over a long enough period to provide the necessary cushion for the private sector to achieve parity with the US. Hence there does appear to be some linkage between the relatively weak overall position of the European electronics industry and the lack of government intervention - although obviously other factors are involved (see particularly Dosi, 1981 on this point).

This pattern has changed since the mid-1970s when European governments, again alarmed by the growing dominance of the US and now of Japan, began sharply to increase their level of support - not only for the electronics industry but also for other areas microelectronics diffusions. This is shown by Table 4.1 which gives details of recent and on-going government programmes of support.

TABLE 4.1

Government R&D Assistance for Electronics in Selected OECD Countries

Country	Date	Project	US$ (millions)
US	1978-82	VHSIC and non-VHSIC R&D	279.0
Japan	1975-81	LSI ICs for computer telecommunications and microwave	180.0
	1976-79	VLSI	123.0
	1980-91	Optoelectronics	77.5
	1982-90	Supercomputer	92.3
	1982-89	New function elements	100.4
EEC	1982-83	Esprit pilot project	11.4
	1984-89	Esprit	744.0
France	1978-82	Plan composants	40.0
	1982-86	2nd plan composants	517.0
Germany	1974-78	BHFT electronic components	157.0
	1981-82	BMFT electronic components	110.0
	1981-84	VDI R&D	0.9
UK	1983-88	Advanced information technology programme	308.5

Other Government Assistance Programmes

Country	Date	Project	US$ (millions)
Canada	1979-81	Applications, investment	34.8
	1983	Plant investment aid	8.9
France	1978-82	Plan circuit integre	120.0
	1982-86	2nd plan composants	334.0
Germany	1982-84	Microelectronics applications	185.0
Italy	1982-87	Development programme for electronics	157.0
Netherlands	1981-83	Microelectronics centres	11.4
UK	1977-80	Electronic component industry	40.1
	1978-81	MAP	114.5
	1978-83	MISP	132.3
	1978-82	INMOS	183.3
Switzerland	1978-81	Testing and advisory centre	4.5

Source: adapted from Soete (1985)

Applications incentive programmes may only benefit the producing industry indirectly by widening the market. Some countries have non-specific industrial loan programmes which are not included here (eg Japan Development Bank Funding).

Section 2: U.K. Government Polices Towards Microelectronics

The policies followed in the UK afford an example of the broad range of fronts on which OECD governments are moving to promote the "informatization" of their economies. The areas of support cover direct subsidy of R&D in the electronics sector, a wide range of programmes to promote the industrial use of the technology, support for education and training, and various infrastructural initiatives. In relation to the support for the electronics sector it is perhaps useful to set public assistance for R&D against the role of the private sector. R&D investment in electronics has grown very rapidly since the early 1970s, and since 1975 it has remained the largest recipient of all R&D funds; by 1981 it represented more than 30 per cent of total UK R&D expenditure. As shown in Table 4.2 about half of electronics R&D is government funded - but 90 per cent of this goes to defence related projects. One of the most widely discussed aspects of UK Government support to non military electronics was its backing for INMOS, then a public sector company which aimed to become a significant force in the world market for 64K RAM chips and other devices. Nearly $180 million was provided between 1978 and 1984 to support this venture, about whose ultimate success there is still considerable debate. However, the government later withdrew from the project and INMOS was acquired by Thorn-EMI in mid-1984. The other major initiative that the UK Government has taken in the electronics complex is in relation to its commitment of more than $400 million to its Fifth Generation computer, covering the period between 1983 and 1988.

TABLE 4.2

UK Electronics R&D Expenditure in Industry, 1981

Industry	Total industry	Carried out within Private* industry	Public corps.	Source of finance Privately* funded	Public corps.	Government
Electronic computers	160.8	160.3	0.5	157.4	0.6	2.9
Telegraph and telephone apparatus	279.9	127.7	152.1	68.6	191.0	20.3
Radio and electronic capital goods	610.4	601.5	8.9	147.5	13.2	449.6
Electronic components	81.5	81.5	-	55.4	1.3	23.8
Electronic consumer goods	20.8	20.5	0.3	19.8	0.3	0.7
Total electronics	1,153.4	991.5	161.8	448.7	206.4	497.3
Total electrical and electronic engineering (inc computers)	1,341.9	1,168.2	168.6	590.6	218.4	533.0
Total manufacturing	3,517.9	3,216.5	244.1	2,091.1	299.7	1,127.1
TOTAL	3,798.7	3,413.8	384.8	2,224.2	347.3	1,137.2

Source: Soete (1985)

* including research associations

It is in the industrial sector where the UK Government's policies are of most interest to us. The largest of these is the Microelectronics Application Programme started in 1978 with a budget of $160 million and now set to run at least through 1985. The MAP programme consists of three elements:

- an awareness and training programme which is intended to stimulate awareness of the technology throughout industry. The mechanisms used are media promotions, training seminars of varying length and duration for management and trade unionists, and various other schemes such as the establishment of Information Technology Centres;

- a feasibility and consultancy programme which makes available specialist expertise to help firms explore possible applications of microelectronics; and

- a development support scheme (Also known as the Microelectronics Industry Support Scheme) which provides a subsidy of up to one third of the cost of applications development projects undertaken by firms.

In addition to this broad cross-sectoral approach, several technology- and industry-specific support schemes have been initiated which involve the provision of various types of support for producers and users of CAD/CAM in manufacturing and in electronics, industrial software development, flexible industrial robotics manufacturing systems, fibre optics, and the development of advanced electronic circuits for industry. In education and training an equally wide variety of programmes have been undertaken. They range from providing grants to schools to purchase computers, and setting up various training schemes for school leavers, to supporting joint university/industry research and training activities. In terms of infrastructural development, initiatives involve the creation of a Minister for Information Technology; public ownership, via the British Technology Group, of specialist companies in office technology, including microcomputers, viewdata software products and computer-aided-design - some of which have now been sold off to the private sector; plans to introduce cable/satellite TV; support for a variety of computer link-up projects; and large-scale investment in digital telecommunications systems.

From a Third World perspective the UK programme affords many ideas and insights as to how governments can approach the provision of support for the use of microelectronics technology in industry. Of particular importance here are its efforts to promote awareness among users; to provide access by firms to specialists able to advise on applications; to set up information and training centres; and to subsidize development costs. Any Commonwealth developing country government which seeks to promote the use of MRIs within the economy may find it useful to consult the UK on its policy experiences in this area. There are also studies which examine the effectiveness of these programmes and which offer a number of recommendations as to how they might be improved (see, for instance, Bessant, 1983).

Another notable feature has been the UK Goverment's growing commitment to computer education and training. Within the formal education system there is a three phase programme underway under the Microelectronics Programme for Schools. The first phase (cost £15 million), now nearly complete, involved the subsidized provision of computing hardware (mainly micros) to all primary and secondary schools. The second phase (cost £18 million) aims to provide training to teachers in computer instruction - 50,000 were expected to have been trained by the end of 1983. The third phase, and the most important, involves the development and introduction of courses, educational software and teaching aids. Four centres have been established to generate the teaching packages and some 400 packages have already been produced. The programme also offers incentives to private software firms to adapt their programmes for educational use. Once these educational packages get into the schools, the intention is that students will not only learn how to programme and use computers, but also how the computer works and what the likely social and economic implications of its use will be.

The UK Government also supports other types of training programmes. For instance, it has set up some 50 Information Technology centres to provide training to unemployed school-leavers and adults in computer programming, maintenance and design. The centres are also encouraged to provide services to the local business community on a commercial basis. Numerous other training initiatives are also being supported.

It is clear that the UK, like many other OECD members, is firmly committed to providing its students with the maximum opportunity to become conversant in the language and environment of the information revolution. The details of the programmes being followed will provide useful guidelines for other countries. Developing country governments already face difficult choices in the education area - and the prospect of introducing the cost of computer education into already critically overstretched educational budgets is a daunting one. But given the likely shape of the future it seems almost as if they have no choice.

If we turn to the effectiveness of the UK Government's policy, it is difficult to offer a judgement on the relative success of its programmes, since many have only recently been initiated. Certainly there have been many criticisms of government policy, mostly to the effect that it is less of a policy and more of an eclectic collection of individual programmes that fall very far short of the long term comprehensive strategy that both sides of industry believe is essential (see Bessant, 1983). Otherwise it is feared that Britain will rapidly be reduced to a dependent nation with a domestic industry controlled by foreign firms.

To a certain extent these fears are confirmed by Britain's relatively poor showing in innovation and international trade, as documented by Soete (1985). By comparing Britain's performance in patenting activity (as a proxy for innovative effort) with that of its main OECD competitors, Soete shows that British firms perform rather poorly in a variety of product categories (telecommunications, components, computers, etc.) except for defence electronics products. This is summarized in Table 4.3 which presents Revealed Technological Advantage Indices for the 1963-1981 period based on the share of country patents taken out in the US (the largest market in the OECD). Japan's evolving strength comes through clearly compared to the relative weakness of the UK and Germany.

TABLE 4.3

Revealed Technological Advantage Indices in Electronics, Telecommunications and Instruments for the USA, Japan, Germany, France and the UK, 1963-1981

	1963-68	1975-80	1981
USA			
Electronics	1.03	1.02	1.01
Telecommunications	1.01	1.07	1.04
Instruments	1.00	0.98	0.93
Japan			
Electronics	1.52	1.49	1.48
Telecommunications	1.20	1.26	1.12
Instruments	1.07	1.32	1.36
Germany (FR)			
Electronics	0.87	0.76	0.79
Telecommunications	0.75	0.64	0.58
Instruments	1.24	0.94	0.94
France			
Electronics	1.05	1.01	1.17
Telecommunications	1.32	1.64	1.97
Instruments	0.99	0.86	0.79
UK			
Electronics	1.13	0.91	0.83
Telecommunications	1.29	1.07	1.05
Instruments	0.90	0.87	0.80

Source: Soete (1985)

Table 4.4 confirms the UK problem by considering the trade balance in the electronics sector. Imports are now the prime source of competitive pressure in this sector and the only segment of it where Britain is strong is in electronic capital goods, which are related to the defence industry; interestingly enough, that is where most of the country's public support for electronics R&D is concentrated.

TABLE 4.4

Trade Balance - Export Performance and Import Penetration in the UK Electrical Engineering Sector, 1963-1982

MLH industry group	Trade Balance (Exports - Imports) (£ millions) 1963	1970	1976	1982
Electronics	44	-39	-74	-1,563
364 Electronic components	20	-11	-13	-314
365 Electronic consumer goods	-3.5	-16	-108	-921
366 Electronic computers	0.5	-55	-145	-553
367 Electronic capital goods	26	43	193	223
Related electronic sectors	61	51	109	59
338 Office machinery	9	-5.5	-16	-38
354 Scientific instruments	23	30	77	78
363 Telecommunications	27	26	49	19
Electrical	152	189	485	544
361 Electrical machinery	55	82	311	623
362 Insulated wires and cables	32	41	124	134
368 Electrical consumer goods	28	21	-29	-316
369 Other electrical equipment	36	44	78	103

Source: adapted from Soete (1985)

It would be far too simplistic to suggest that the poor performance of the UK electronics industry is due to the nature or lack of support from the British Government - it is much more likely to be due to failures and shortcomings on the part of the British electronics industry to respond to the challenges and opportunities offered by the new technology. In the case of the support programmes described earlier, particularly those aimed at the industry sector, for all the criticisms made, the programmes represent a good deal of flexibility and innovativeness on the part of government, without which the situation might be even worse. But the growing share of imports in the home market clearly indicates that there is much more to be done.

Section 3: Software Strategies in Singapore

From examples and data already given it is clear that Singapore has managed to develop an impressive electronics capacity. Much of this has come via the extensive involvement of foreign firms in the assembly of labour-intensive products. Now the Government of Singapore has announced a comprehensive set of policies intended to upgrade and diversify the electronics industry. There are four components to its strategy: first, to move out of labour intensive assembly of components and concentrate on production of higher quality components such as ICs and microwave devices; secondly, to extend production of industrial electronics into the full range of computers, peripherals, avionics equipment and electronic measuring equipment; thirdly, to increase the level of automation in consumer electronics; and finally, to establish a world class computer services and software industry.

Most success so far has been in the industrial electronics/computers area. Industrial electronics accounts for only about 5 per cent of Singapore electronics output and it is hoped to increase this to 20 per cent by 1990. Foreign firms have already invested more than US$100 million in computer assembly and peripherals production facilities, e.g. Digital Equipment Corporation (mini-computers), Micro-Peripherals (floppy disc drives,) Apple Computer (micro-computers and encoder boards); Juki (Chinese script word-processors); Astec International (high-frequency power switches and IC production and testing); Tata-ELXSI (multi-processor high speed computer). 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 aspect of policy we want to highlight here is the explicit concern of the Singapore Government to develop an export-oriented software industry. This represents the most concerted effort in this area throughout the Third World, though there are of course some underlying reasons why Singapore is a special case. It is for both of these factors that a further examination may be useful. There are three elements in the Government's software strategy: first, a rapid increase in the level of computerization of the civil service, industry and the services sector; secondly, an expansion of the country's stock of trained computer and software professionals; and thirdly, direct promotion of an export-oriented software industry.

To *increase the level of computerization*, the government plans to invest more than US$100 million to computerize ten ministries over the next decade. Equivalent emphasis is being given to introducing computers into the commerce, banking and finance sectors, with the result that more than 2,000 minicomputers are expected to be installed over the next three years.

The rapid *expansion of computer services and the software training and education programme* is the cornerstone to Singapore's software strategy. The education programme is intended not only to increase the pool of computer manpower but also to meet the academic requirements of the computer sector, provide opportunities for retraining existing engineers, and increase user awareness of the need for investment in computer hardware and software.

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 for nearly 8,000 software professionals is expected to emerge over the next eight years. With a current stock of only 1,200 professionals, the government has allocated $110 million to the creation and operation of a variety of training schemes and institutions designed to close the gap as rapidly as possible. This represents a thirteen fold increase over the previous amount. Ten million dollars of this fund has been allocated for overseas graduate scholarships in computer services and software (Wills, 1983).

Previously, Singapore's software and computer professionals came largely from the in-house training programmes of TNC computer vendors and large computer users such as banks and insurance firms. As part of its training initiative, 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 700-1,000 trained software professionals. Table 4.5 gives details on each of these institutions, one of the most interesting features is that each one has been set up with the collaboration of *different* foreign countries/firms. All these institutions were established and are under the control of Singapore's Economic Development Board, which is responsible for the overall electronics programme.

TABLE 4.5

SINGAPORE'S SOFTWARE EDUCATION AND TRAINING INSTITUTIONS

1. Institute of System Science:

   Established October 1981. Collaborative effort between National University and IBM. Trains 100 systems analysts yearly plus courses for senior executives.

2. Centre of Computer Sciences:

   Established in 1983. Collaborative effort between British Council and Nyee Ann Polytechnic. Trains 200 programmers annually.

3. German-Singapore Institute of Production Technology:

   Established in February 1982 to train production engineers and technicians in software engineering.

4. Japan-Singapore Institute of Software Technology:

   Established in February 1982. Collaborative effort with Japanese government. Trains 300 middle- and senior-level management personnel yearly in computer applications.

5. French-Singapore Institute of Electro Technology:

   Established in April 1983 and specialises in training software engineers in industrial applications.

Source: Compiled from Wills (1983).

TABLE 4.6

INCENTIVE SUPPORT SCHEME FOR SOFTWARE INDUSTRY IN SINGAPORE, 1983

1. Export Incentives:

   90 per cent tax exemption on all profits above minimum base which result from export sales. Granted for 3 to 5 years.

2. Pioneer Status Incentive:

   Total tax exemption and 40 per cent on corporate income tax for 5 years for firms engaged in sophisticated software development.

3. International Consultancy Services Incentive:

   20 per cent tax write-off on export profits for software companies with gross export income of more than $1 million.

4. Tax Incentives for R&D:

   a) 200 per cent deduction on R&D costs
   b) accelerated depreciation for R&D equipment
   c) 50 per cent investment allowance on R&D capital investment
   d) capitalization of license payments

Source: Compiled from Wills (1983)

Finally, the fostering of an export-oriented software industry depends both on the creation of domestic firms (a target of 40 firms of over 100 employees each has been set) and on the attraction of foreign software firms. A programme of incentives has been enacted and Table 4.6 gives details. Many Japanese, European and North American firms are exploring possibilities and a number have already established themselves locally. They include IP Sharp (Canada), Societe Generale de Service et de Gestion, and IX Conseil (France), EB Commuications (Norway), and Fujitsu (Japan). As part of this initiative 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 Centre. The latter will have a number of firms (with a total personnel of 1,800) who will concentrate on R&D and export-oriented software development.

There are other dimensions to Singapore's strategy and position that need to be introduced here. Since software is a labour intensive industry, the strategy being pursued places a great demand on skilled labour. And while steps are being taken to train Singaporeans, it is conceivable that labour shortages will constrain the pace at which the policy can be implemented - even despite the growing "import" of skilled persons from other countries in the region. This could benefit Singapore but might work to the detriment of neighbouring countries.

Further, if Singapore does succeed in this strategy it will only partly be because of the strategy itself; there are other factors which place the country in a unique position vis a vis other, particularly poorer, developing countries. The country already has a substantial electronics industry (nurtured by an attractive location and generally positive government policies) and related productive technological capabilities. There is a strong entrepreneurial class fostered by a conducive environment. This means that the domestic savings rate is high, allowing the economy to afford expensive training policies. Those qualifications obviously suggest that Singapore's software policy cannot be transferred wholesale to other 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. Obviously other developing countries do not possess the advantages of Singapore; nor are we suggesting that they should opt for an export oriented software industry. 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.

Section 4: Development of an Electronics Capability in India

India possesses an industrial sector that is already diversified, growing rapidly and increasingly sophisticated. This progress has been accompanied by rising per capita incomes and growing consumer expectations. The country, therefore, faces the challenge of developing a diversified electronics industry capable of meeting what will be a continually expanding demand for electronics products, computers and components - in a sector where, as we have seen, the technology has changed dramatically in recent years. 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 1970/71.

Through the efforts of these specialized agencies Indian policy until 1980/81 was 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. These 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 centres (18 in all). Foreign involvement in the sector in the 1970s was strictly limited to specific areas.

As Table 4.7 shows, these efforts led to very respectable growth in output, averaging 19 per cent per annum during 1973-1983. Export performance was however much more varied, with most of the growth limited to software components and products assembled in the Santa Cruz Export Free Trade Zone. Even this rapid growth in production was insufficient to meet demand. Consequently, imports averaged around 35 per cent of domestic consumption between 1976 and 1983 (Agarwal, 1985). Over the course of the Seventh Five Year Plan (1985-1989), the Department of Electronics expects demand to rise much more sharply than in the past, registering an annual rate of growth of 42 per cent.

TABLE 4.7

Production of Electronics in India, 1973-1983
(in million rupees*)

	1973	1976	1983
Consumer electronics	640	1,030	3,300
Communication and broadcasting	580	1,100	2,700
Aerospace and defence	330	500	1,260
Computer, control and instrumentation	220	640	3,290
Components	510	800	2,300
SEEPZ (export)		30	750
TOTAL	2,280	4,100	13,600

Source: adapted from Agarwal (1985)

* 12 rupees = 1 US$

It is also interesting to discuss the results of government reviews of the performance and problems of the Indian electronics industry (Government of India, 1979a, 1979b). One of these focussed specifically on the electronics components sub-sector, which necessarily lies at the heart of India's attempts to strengthen its electronics capabilities. Several major weaknesses were identified. 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 per cent of the output consisted of discrete devices largely intended for the consumer electronics industry. Total output was very small and what was produced was of low quality and high cost - the latter being due mainly to local scales of production being between three and fifty times below international standards (Sigurdson, 1983). 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.

In response to these problems and in recognition of the crucial role to be played by components, a variety of growth-oriented measures have been introduced which emphasise increasing the supply and range of components produced at world scales of output. First, fiscal and financial incentives were introduced to allow a higher rate of depreciation on components and a reduction in import duties on such equipment and on material inputs. Second, a new industrial licencing and foreign collaboration policy was introduced. Technology imports were freely allowed if suitable to establish production capacities on an internationally viable scale. Third, emphasis in production planning is being given to exports as well as to domestic markets. Finally, more public sector supported enterprises have been established. The most important of these is a $100 million investment in Semi Conductor Complex Ltd (SCL) 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, electronic 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. Technical collaboration agreements have been signed with AMI of the US for transfer of state of the art LSI and VLSI technologies. A full design centre is also being established. LSI wafer fabrication was expected to commence in October 1983, carried out at first on imported designs and masks whose local production is expected in the next few years.

There is one other important element of the analysis carried out by the Government's Review Committees which has much wider relevance. This relates to a series of problems identified 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. Much emphasis was placed on the unduly complicated and over bureaucratic application procedures, which often resulted in untenable delays in reacting to decisions and issuing instructions. These problems occurred not only in giving initial approval but also in the issue of letters of intent and import licenses. Even when approval was granted, it was often felt that government officials unnecessarily interfered with and amended project proposals without reference to the entrepreneurs involved. The following quote succinctly summarizes these complaints.

> "A critical analysis of the present status of the electronics industry in the country shows that the investment, production and employment generation of the elaborate structure for screening and rigid control on all matters connected with the licensing of expansions or new capacities and approval of projects in this sector .... the emphasis so far seems to have been more on regulatory rather than on development and promotional aspects .... this situation in electronics seems to have stifled initiative and enterprise, even in the case of small entrepreneurs and self-employed technocrats, by subjecting them to time-consuming procedures and multichannel scrutiny. Final approvals to projects and schemes have ranged over varying periods and up to as much as sixty months from the date of application; even when approvals were granted, major modifications seen to have been made in many cases somewhat arbitrarily superseding the entrepreneurial judgement in respect of the techno-economic viability of proposals .... there has been needless and rigid control, strangling growth and causing frustration" (Government of India, 1979a, p.13, cited in Agarwal, 1985).

There is much of value in this assessment for other developing countries seeking, at whatever level, to stimulate the development of an electronics sector via state intervention. This is an issue we return to in the final chapter.

Apart from being able to learn from the government's frank assessment of the status of the country's electronics industry and state policy mechanism, the Indian experience offers other useful insights, particularly in the area of training where various initiatives have been taken to upgrade the quality of the country's electronics personnel. One of the more notable of these is a course developed by the National Centre for Software Development and Computing Techniques (NCSDCT) in Bombay. This course was set up to give programmers rudimentary skills and formal training in computers. The teaching method is based on the students' use of individual, self-contained modules, each of about two months' duration. These modules emphasize programming methodologies, the use of programming tools and the development of common applications in engineering and management.

The course has been judged highly successful due to a number of factors - use of the module technique allows students to pace themselves; only one third of the training involves formal lectures, with most of the time allowed for hands-on-practice; instructors are readily available as are opportunities for the students to use computers; the course is part-time and relatively inexpensive (less than $200), with subsidies available. (Narasimhan, 1984).

Section 5: Policies in Other Commonwealth Countries

As might be expected, most other Commonwealth developing countries are at a much earlier stage in the formulation of policies in the area of microelectronics. Most do not yet have an effective science and technology policy. Where these do exist, they tend to be much more concerned with traditional science policy issues such as allocation of R&D funds. Similarly, the various institutions which have been set up, such as Science Promotion Councils and various research institutes, also focus on science activities.

While the development of science must clearly be a priority for these countries, rarely are any effective links made with the productive sector, whose performance is severely constrained by the lack of technological capacities. Even the network of industrial research institutes that exist in many countries make little effective contribution to the development of technological skills within productive enterprises.

The constraints that this situation imposes on the developmental potential of the economy are well known and we address them in more detail in the next chapter. Here we simply wish to note that the lack of a coherent set of technology policies must inevitably place severe limitations on what these countries can do in the area of microelectronics.

Nevertheless, several countries have developed policies which deal with some of the issues raised by the technology. Some are attempting to stimulate the creation of an offshore assembly type of electronics industry dependent on foreign firms and based on the government's perception of the country's labour cost advantages. Sri Lanka, for instance, is promoting both software and components exports and has already attracted some foreign firms. Jamaica is also trying to woo component assembly firms - and in so doing is in direct competition with an already established production site in Barbados, as well as with the Government of St Vincent which is offering a wide variety of incentives (now typical of those offered by many countries). Given our analysis in Chapter 3 on trends in the component industry, the viability of such policies in the longer term needs to be examined very carefully.

Many of the poorer countries do have rudimentary electronics industries, primarily assembling consumer electronics products from imported components. However, since many of these countries face severe balance of payments constraints the industries are suffering from substantial underutilization of capcity. This is in strong contrast to the profusion of VCRs, tape recorders and other electronics products which still seem to be flowing into many of these economies and, in the process, shaping future patterns of consumer demand.

Apart from attempts to stimulate the development of an electronics industry, the only other area where governments have initiated policies relates to the import and use of computers. A number of governments have formed special groups or committees to increase the development of data processing activities and occasionally to control the import of computers. As we noted earlier, these policies stem from their experience with the use of mainframe computers in the public sector in the 1960s and 1970s and signal a concern to rationalize and upgrade data processing capabilities and to benefit from the advantages offered by microcomputers. Below we briefly describe some of these initiatives.

Sri Lanka has established a National Computer Policy Advisory Council and a central computer secretariat under the office of the President to formulate a national computer policy. In addition to trying to foster an export-oriented hardware and software industry, these institutions are pursuing initiatives in computer education, computer applications within the public sector, telecommunications and data transmission facilities. Particular emphasis is on creating centres of excellence in education and R&D in universities, in upgrading management capabilities regarding the use of computers, and in developing a national capability to evaluate and acquire foreign computer technology when necessary.

The Government of Bangladesh has formed a National Computer Committee with wide-ranging terms of reference:

> "(a) Formulation of strategy and policy guidelines for promotion and strategic transfer and development of computer technology in the country.
>
> (b) Identification and selection of application areas and fixation of their priorities.
>
> (c) Formulation of action plan for developing access to trained manpower.
>
> (d) Formulation of policy guidelines for -
>
> > (i) procurement and installation of hardware and software from abroad
> >
> > (ii) standardization of hardware and software as an industry
> >
> > (iii) ensuring optimum utilization of hardware particularly the mainframes
> >
> > (iv) promotion of higher training and reasearch in the field of computer science and its applications
> >
> > (v) control and supervision of private sector training activities

(vi) promotion and development of requisite infrastructural facilities for rapid computerization

(vii) after-sale service and maintenance by the manufactural suppliers

(viii) allocation of resources for promotion and maintenance of hardware

(ix) procurement of spare parts and supplies for computer equipment and related infrastructural facilities

(x) providing assistance to the prospective users in respect of configuration, software and systems development

(xi) improvement and harmonization of emoluments and other service conditions of computer personnel in the country

(xii) computer activity at national, regional and international level".

(Bangladesh Observer, March 1983)

One of the most crucial of these terms of reference in the short term is the development of skilled personnel and facilities to repair, adapt and maintain imported computers so as to avoid dependence on manufacturers. This is a problem obviously relevant to all countries. The experience in Bangladesh has been that once vendors sell the system they tend not to provide much support when problems arise.(1) Most vendors concentrate their efforts on selling. The exceptions to this are some of the bigger companies such as IBM and NCR who do have trained personnel available. However, it is clear that as more microcomputers are imported and sold, users will face maintenance problems until steps are taken to ensure an adequate supply of trained personnel.

Most Commonwealth countries in Africa do not yet have explicit computer policies. This is despite the fact that many already use computers in the public sector, that installation continues, and that computer vendors do operate. For instance in Ghana between 1980 and 1984 some 21 mini and mainframe computers were installed in the public sector, mainly by local subsidiaries of IBM and Wang. Yet there is no explicit policy in the area except that payments for services must be made in local currency.

Among the countries which do have explicit policies are Nigeria and Zimbabwe. In Nigeria, a Central Computer Committee has been established whose main objectives are overseeing the rationalization of data processing activities, supervising the importation of computers and controlling the operation of foreign computer companies trading in the local market. In the 1970s, the Government imposed a decree requiring these companies to transfer between 40 and 60 per cent of their equity to local shareholders. Some companies such as UNIVAC balked at this pressure, but both IBM and ICL complied.

Zimbabwe is rather better placed than most African countries to develop capabilities to use computers in administration. However, although there are some skilled personnel capable of programming, maintenance and even system design, there is still a severe shortage of such personnel which is hampering the Government's efforts to utilize existing systems and expand its computing capacity. The problem is further exacerbated by a lack of awareness among some officials of the value and need for computers to assist in the decision-making process. Some steps are being taken to overcome the shortage. The Ministry of Economic Planning and Development, along with the Ministry of Manpower Planning and Development and the Public Services Commission, have instituted a series of three day "awareness" courses for government officials. A computer centre is also being established, with the help of foreign aid, which will perform training functions. And the University of Zimbabwe has recently acquired 13 NCR microcomputers for use in its computer sciences courses. It is the intention of the Government to continue to give priority to the expansion of computer education facilities by establishing computer science departments in other educational institutions (Microelectronics Monitor, nos 5, 8 and 9, 1983 and 1984).

Computer Policy in Other African Countries

It is interesting to note that some other African countries, particularly in Francophone Africa, are somewhat further advanced of computer policies. Many of their initiatives have been strongly supported by the French Government. In Algeria, in 1967, a National Commissariat for Informatics was created to develop and implement policy, and training institutions and national data processing centres were also established. In July 1978, a National Informatics Plan was adopted. This centralized responsibility for controlling imports of data processing equipment in one institution, with a mandate to ensure compatability. Minicomputers have been assembled using imported components since 1979 and the Algerian Government has a strong committment to develop a national software capacity. Extensive attempts have been made to improve the functioning of public services via the use of information processing equipment. For instance, the national postal cheque system has been computerised to stop its deterioration and handle the growing volume of transactions. The results are shown in Table 4.8.

TABLE 4.8

Impact of Computerisation on Algeria's Postal Chequing System

	Manual 1974	Computerised 1977
Number of operations	24,360,000	33,620,000
Volume (millions DA)	109.5	210.8
Number of accounts	452,000	709,000
Waiting time at centres before processing of document	15 days	2 days
Payment at cash-desk	3-6 hours	2 minutes
Saturation ratio	95%	50%
Employment	856	680

Source: adapted from "L'informatique en Alérie", Algers (1978), RADA (1983)

Similar initiatives have been taken in the Congo, Ivory Coast, Morocco, Togo, Tunisia and Zaire, and all these countries now have some form of national policy with stated objectives, backed by administrative implementation units and training institutions. There are summarised in Table 4.9.

TABLE 4.9

Summary of Informatics Plans and Institutions in Francophone Africa

Country	Responsible Institution	Date of Estab.	Objectives and Responsibilities
Congo	Congolese Office for Informatics	1972	Responsible for public sector data processing and teleprocessing policies and systems. Overseas personnel training, modernization of telecommunications networks, access to international data banks and creation of a national data bank. 1982 - 1986 Data Processing Plan focusses on personnel training and equipment harmonization.
Ivory Coast	Office Control de Mecanographie	1967	Initially responsible for public sector data processing
	National Commissariat for Informatics (NCI) General Secretariat for Informatics (SCI)	1980	NCI responsible for developing 1981-1985 Informatics Plan; SCI is responsible for implementation. Overall objectives to upgrade national data processing systems; upgrade personnel; negotiate with computer manufacturers; create industrial computer using capacity.
Morocco	Commission for Data Processing	1967	Upgrade national data processing capability and establish national information systems; provide data processing services for industrial firms; training; ensure equipment compatability; implementation of national teleprocessing network; undertake local manufacture of data processing equipment.
Togo	National Centre for Research and Informatics Treatment	1982	To upgrade and optimize public and private sector data processing capabilities; advise on system acquisition; develop national data processing plan.
Tunisia	National Center for Informatics Permanent Secretariat for Informatics	1977 1982	Control of public sector data processing systems; control over system acquisition and supplier selection; training via National Centre for Informatics Sciences; implementation of a National Centre for Maintenance of Scientific Equipment.
Zaire	Permanent Informatics Council of Zaire	1976	Development of Informatics Master Plan intended to upgrade national data processing capability and provide training.

Source: Compiled from Delapierre et al (1983)

To sum up, the bulk of Commonwealth experience with microelectronics policies is, as might be expected, concentrated in the developed member countries and a few of the more advanced developing countries. Though limited in scope, the policy expertise developed in these countries does provide other Commonwealth countries with a rich pool of resources to draw on. It is clear that some of the poorer countries are moving towards establishing some policy mechanisms. Whilst these mechanisms are generally limited to computer usage and training, this makes sense since this is the main area of impact so far. Apart from the need to stimulate the formation of similar policy structures in other countries and improve those that already exist, one of the greatest priorities is to provide training facilities in computer usage, programming, repairs and maintenance. These issues are taken up in the next chapter.

Footnote to Chapter 4

(1) Personal communication from Dr Quazi Ahmed, Assistant Professor, Dacca Institute of Business Administration.

CHAPTER 5

POLICY ISSUES AND OPTIONS

In preceeding chapters we have attempted to build up a picture of the main trends and implications of the microelectronics revolution. The developed countries face an extremely broad policy agenda as a result of the pervasive character of the technology and the complex economic and social changes that will accompany its diffusion. These changes are occuring so rapidly that it is imperative that policy-makers in those countries formulate a comprehensive set of policies that deal with both the short and the long term problems.

From the perspective of the developing countries one could argue that the technology's effects will be equally pervasive and that these countries too must develop comprehensive policies. Indeed, a number of analysts and institutions such as UNIDO have been propounding such a view and urging the formulation of national "informatics" policies as a main priority for the Third World (IBI, 1980; Nolan, 1983). There can be little doubt that the technical, economic and social changes associated with this technology will profoundly alter the global context within which the Third World pursues development in the future. Policy-makers must become well informed about the nature of these changes so that they can respond in a reasoned manner: and this should ideally be done on the basis of a comprehensive policy framework.

In this chapter we have not attempted to develop such a framework. Rather, we will first discuss policy options and issues associated with the creation of a national electronics capability. This will be followed by consideration of "applications" policies and the need for creating an hospitable environment for the use of computers. Issues related to the implications for export-oriented industrialisation policies are discussed next, and the chapter closes by considerating some of the policy issues raised by the use of MRIs in industry in the Third World.

First, however, there are some further introductory comments to make. There are many reasons why most of the poorer developing countries do not yet have an effective set of explicit technology policies. Policy-makers in these countries frequently do not recognize the crucial role of the technological factor 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. As a result, existing mechanisms and institutions allegedly concerned with science and technology policies are either ineffectual or are concerned solely with science. In this case there is often an assumption that the development of technology will somehow follow automatically from that of science. This is certainly not the case and though the two are obviously related, given the essentially technological nature of many of the constraints confronting these countries, the need for a separate focus on technology policy is paramount.

Another set of problems of particular current relevance is that many governments are totally consumed with the short term problems of trying to maintain their countries' integrity under conditions of severe resource constraints. Hence it is not surprising that the development of technology policies in general and informatics policies in particular receive little attention. This is understandable but it would be a mistake to believe that the severity of the crisis has nothing to do with technological factors. In fact they are central. Take, for example, the way in which the lack of foreign exchange restricts some economies' ability to import essential inputs, intermediates and spare parts. Because of the lack of these inputs, capacity is underutilized and the economy suffers high social costs. Many of the plants which are now virtually closed down because of this have been established for a number of years and do not incorporate very sophisticated technologies. In many cases the spares and intermediates necessary to run the plant could have been produced locally. Had past policy, in fact, 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 many would point to as 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.

One could make a similar point in relation to the efficiency of energy use. After the first oil price rise in 1973, industry in the developed countries responded by becoming much more efficient users of energy. They did this by using their technological capabilities to effect a wide range of (often minor) innovations to improve the energy efficiency of existing techniques. The burden that high energy prices imposed on the economy was therefore reduced considerably. Many developing countries were unable to respond in the same fashion (and are suffering as a result), at least partly because they lacked the technical skills needed to modify existing plant and equipment. And they lacked these skills, because government and entrepreneurs had not previously invested in their creation.

The final set of general comments we wish to make are related to the above emphasis on the importance of technological capabilities but deal specifically with government policies towards technology transfer. When Third World public and private sector firms import technology, their main concern is usually to increase their <u>productive</u> capacity as cheaply and quickly as possible. Explicit government policies on technology transfer (where they exist) reinforce and indeed foster this approach. Technology transfer is seen by government merely as a way of obtaining the plant necessary to increase the economy's capacity to produce certain goods. The much publicized debate in the 1970s over the monopoly prices and restrictive practices imposed by TNCs on Third World importers of technology influenced government policy in this area: most policies aim to reduce the price, eliminate the restrictive practices and shorten the duration of the contract related to technology transfer.

Little effort is put into acquiring <u>technological</u> capacity along with the productive capacity. Recipient firms get the hardware and some operator training but rarely acquire the underlying knowhow and expertise required to improve and adapt the imported techniques. Many problems arise as a result of this failure to use the technology transfer process as a "learning" mechanism. Among the most important is that the performance efficiency of imported plants often declines over time - whereas in developed countries, 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 developing countries. The social costs of this are extremely high. Studies carried out at the University of Sussex Science Policy Research Unit, on technology transfer and post-investment plant performance in some 10 fertilizer and textile plants in Tanzania and Bangladesh show a consistent failure of local personnel to be substantively involved in the design and engineering parts of the transfer process, and a continual decline in operating efficiencies due to the absence of engineering and design skills within the plants.

By not striving to maximise the learning component of the transfer process, developing countries 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, to develop managerial capabilities. Some Third World firms do actively pursue the acquisition of technological capabilities via technology transfer - but most do not. This situation can only be remedied by explicit technology policies on the part of government.

The above points are not only relevant to all the issues discussed subsequently in this Chapter but add up to an argument for Third World governments to place the technology issue at the top of their development policy priorities. The current crisis in many developing countries and the emergence of new technologies make this, if anything, even more essential than before.

Section 2: Policy Issues in the Electronics Complex

The formulation and implementation of public policy towards the microelectronics sector in developing countries must be predicated upon an understanding by governments and financing agencies alike of the "heartland" nature of microelectronics technology. The pervasive character of the technology and its wide-ranging effects on both the electronics complex and downstream industries suggest the need for a set of policy responses that go beyond those associated with the development of other sectors whose linkages are much more limited. The phenomenon of pervasiveness also implies that virtually every developing country will be confronted with the need to formulate and initiate policy in relation to the electronics sector at some level.

For many smaller countries, such policy responses may be limited to rationalizing imports of electronics-based products and ensuring the availability of sufficient numbers of trained personnel to select, adapt and operate imported systems. For larger countries, the mode and means of establishing or extending production of electronics products for the domestic and/or export markets will become a central concern of industrial strategy.

In both groups of countries, policy formulation requires accumulating a large amount of detailed information on domestic and international trends on which to base decisions. Such efforts must incorporate the commonly understood notions of technology assessment but oviously include much more. Specifying the nature of the information required is beyond the scope of this report. In this section, therefore, we concentrate on discussing some of the main issues likely to be relevant in policy formulation.

There are many topics under this heading. Here we focus on five: the need for state intervention; the importance of selectivity; the need for policy comprehensiveness and co-ordination; policies for technology acquisition; and policies for training.

Necessity for state intervention

The experience of most countries - developed and developing - underlines the central importance of state involvement in the development of the microelectronics sector. In most countries with established policies, government policy-makers recognize that the state must play a major role precisely because of the unique and pervasive character of microelectronics technology. This need to intervene arises for three reasons. First, as an economy expands, its expansion will increasingly be linked to a growth in electronics-related products and services, either as final output or as inputs into other goods and services. An economy with a limited electronics capacity will be dependent on high cost and conceivably inappropriate imports. The state has a role in stimulating the creation of a national electronics capability to meet national needs and in minimizing the social or economic damage caused by the introduction of inappropriate technologies.

Secondly, despite the high potential gains that can arise from an electronics sector, new entrants face the twin difficulties of overcoming fierce competition while at the same time mastering an (often) entirely new technology. As a result private or public sector firms may be unwilling or unable to meet the costs of entry on their own because of the high risks involved. Governments can reduce these risks by creating conditions within which these firms can become competitive over time.

Thirdly, as argued in section 2 of Chapter 3, the situation may arise where developing country firms must incorporate the technology in their products and/or processes, or lose their ability to compete. An electronics capabiity is essential to facilitate the introduction and efficient use of the new technology. While it is arguable that markets work well in encouraging the efficient production of current goods and services, they work less well in persuading firms to invest in entirely new ways of doing things or in moving into new industries altogether. The problem is likely to be even greater in Third World economies where markets are usually "distorted". In these circumstances, governments can enhance the rate at which capital, labour and technology are recombined to respond to changes in international or national markets.

Need for selectivity

No developing country can undertake the simultaneous development of all segments of the electronics complex. The skill, resource and infrastructural requirements are simply too great. Again, the experience of many countries shows that strict selectivity of the subsectors, products and even firms where resources are to be concentrated is essential. This is particularly true if governments wish to develop an export capability, since low wages are no longer the key to success in international markets.

This does not mean that entry into electronics production for export is not feasible but only that choices must not be made solely on the basis of a passive and reactive desire to be involved in such production simply because of its short term employment and income effects. These can be considerable - however it seems to us that the possibilities of greater long run externalities can be enhanced if the selection of products and segments for development also considers the nature of existing capacities and domestic market potential as a basis on which to move into exports. Needless to say, the smaller economies are likely to face much more severe restrictions when moving from domestic production into export - and for many of these the option of developing an export capacity must be considered remote.

We cannot here specify which products and segments are the best candidates for development in particular countries. Obviously for countries at a less advanced stage of industrial development, consumer electronics are going to offer possible entry points provided care is taken with the nature of the products and the willingness of the technology supplier to co-operate in developing the capabilities of local assemblers and component producers.

More generally, government should choose products and segments on the basis of an assessment of the following factors:

(a) existing pattern and trends in local demand for electronics products to determine priorities (e.g. microcomputers, specific types of consumer electronics, components related to their domestic or export production, softward needs, agricultural applications, etc);

(b) availability of private and public sector resources in terms of industrial structure, skills, capabilities of local and foreign firms, comparative advantage in other areas, etc;

(c) likely responses of existing domestic producers, existing foreign producers, and prospective overseas markets to new initiatives;

(d) assessment of trends in demand and competition in regional and world markets at a product, subsector or firm-specific level;

(e) likely technological trends and implications of these on barriers to entry, potential for upgrading local resources, demand for current products, production and investment strategies of foreign subsidiaries, etc;

(f) conditions governing supply of technology, both locally and internationally, among NIC and OECD firms, from large and small suppliers, and from mature or state of the art products; and

(g) clear consideration of the opportunity costs of new investment in electronics compared with other sectors. This is particularly important for smaller countries at less advanced stages of development. Returns to investment in electronics may be a long time coming - yet the gains may be significant even for smaller countries.

Comprehensiveness and co-ordination in policy regimes

State involvement in electronics as in other sectors, usually occurs at two levels. The first is where the state acts in a regulatory capacity in setting the framework within which firms operate. This includes control over imports and exports, policy towards foreign investment, regulation of competition in local markets, provision of credit for investment or of subsidies for R&D and training, and provision of investment in infrastructural facilities such as education, communication, transport, etc. The second type of state involvement comes from its role as a part of the market. This occurs by direct participation in production or via procurement policies. The latter is particularly important because the scale of public sector involvement means that it can readily influence the orientation of producers and even the direction of technical change.

Given this degree of involvement government policy measures should be comprehensive as well as co-ordinated and complementary. Stimulation of both supply and demand elements should be pursued and co-ordinated - dealing with only one is unlikely to achieve desired objectives, as some OECD governments have found. For instance, in the last few years the UK has concentrated policies on stimulating demand among microelectronics user industries because previous supply-side policies were not leading to rapid uptake of the technology. At the same time, both macro- and micro-economic policies also need to be used. For example, the imposition of a protective tariff or use of market reserve strategies are both macro policies designed to foster development of local firms. However, it is highly unlikely that these policies will succeed on their own, as the local firms' ability to compete internationally and/or supply a reliable, competitively priced component locally will not happen automatically because there is a protective tariff. Care must also be taken on the one hand to ensure some form of domestic competition and on the other to provide direct support to specific firms for technological development.

Government procurement policies are a crucial but often unrecognized mode of intervention. In many developing countries, governments probably account for more than 50 per cent of the market for electronics products. Yet most countries do not use procurement as a means of stimulating local industry. Procurement strategies can operate in a number of ways. First, governments can offer local firms the opportunity to compete for supply contracts or they can simply reserve the contract for local firms. This gives the latter a secure market, reduces their risks and creates a learning opportunity. Second, through the use of component/equipment performance requirements, the public sector can stimulate local firms to achieve internationally competitive quality and cost standards. Third, publicly stated procurement policies which favour local firms can be used to alter existing relationships with electronics suppliers most of whom at present are likely to be foreign. The bargaining position of local firms can be strengthened vis-a-vis foreign competitors.

Policies should ideally be formulated and implemented either by a centralized body or perhaps more preferably by a co-ordinating committee with the necessary power to ensure public and private sector co-operation. Facilitating legislation and/or some type of executive directive should be in place to strengthen the policymaking body. Too much co-ordination is clearly as bad as too little, particularly in an industry which demands a high degree of flexibility and change. The right level of co-ordination and centralized control can only be worked out in relation to specific circumstances - the main point to be recognized is the need for some form of central body responsible for policy in the microelectronics sector. As we saw in Chapter 4, some countries are moving in this direction in their policies on computer usage and a similar strategy should be adopted to the microelectronics sector as a whole.

Policy issues in technology acquisition

Given the relatively underdeveloped state of the electronics sector in most developing countries, technology acquisition from foreign suppliers will be an essential feature of policies for this sector. At the level of firm-to-firm transactions, there is often concern that the right "mode" of technology transfer be selected via TNC subsidiaries, through joint ventures, and through arms's length licensing arrangements. Unfortunately, there is little evidence to suggest that one mode is better than another. In fact, the experience of technology transfer in other sectors, on which there is much more evidence, suggests that the mode of transfer is a less important determinant of effective technology transfer than (a) the initial absorptive capacity and bargaining strength of the recipient; (b) the degree to which the recipient/government places a high priority on effective absorption and its willingness to pay the price to acquire the knowhow and skills required; and (c) the way in which the transfer process itself is organized and monitored, i.e. the level and nature of training/ learning components built into the transfer agreement and the "performance" guarantees required of the suppliers. What we mean here by performance guarantees relates not only to the physical performance of whatever facility is acquired but also to the performance of the suppliers in giving the recipient access to the required knowhow and to an effective demonstration by the recipient that the knowhow has actually been assimilated.

Given market demands for rapid change, recipient firms in the electronics sector, perhaps more than any other, need to maximize the rate at which they absorb imported technology and develop their own innovative capabilities. Both the firm and the government must take explicit steps towards this objective - a passive approach to technology transfer will only result in permanent technological dependency. This suggests that an overriding concern in technology acquisition must be to maximize the training component of any agreement, with the explicit proviso that training be provided in core areas of design and process knowhow.

These points are relevant not only to the electronics sector but to the many other sectors where developing countries will for some time be dependent upon the import of foreign technology. They apply particularly to the managerial components of technology.

Some suggestions for training

The electronics industry is skill-intensive and a shortage of trained personnel is everywhere the main constraint on its development. For many developing countries, the accumulation of a critical mass of skilled manpower will be the means of overcoming the key barrier to entry. To a large extent the amount and nature of resources which government is prepared to invest over the long-term in training will be one of the most important determinants of a country's ability to develop a well-integrated electronics capability.

Perhaps more than most sectors, initial skill development in electronics depends on formal training. This can be imparted through programmes organized at a number of levels. It is an area ideally suited for public sector support either via the direct creation of training institutes or through the provision of subsidies to existing programmes and facilities. Among the options are:

(a) basic software training courses for high school students/ graduates to generate the cadres of low-level programmers which will be needed in the government and commercial sector;

(b) electronics-related work in university degree courses with particular emphasis on engineering. The options range from the creation of separate degree courses for electronics engineers, to offering related courses for existing degrees in mechanical engineering, chemical engineering, etc. Downstream diffusion of microelectronics depends crucially on individuals who encompass both the traditional skills associated with their craft (e.g. mechanical engineering) and electronics/software capabilities;

(c) special institutions designed to train people for specific tasks. The type of training can vary widely, but particular attention should be paid to training for lower-level software programmers/technicians/maintenance and repair personnel and for systems designers. The latter skills are crucial in developing countries since they allow people/firms to enter product design without possessing the much more sophisticated component design skills;

(d) training programmes in large established firms. Support could also be given for in-house training by existing institutions, while government agencies, commercial firms, TNC subsidiaries and/or marketing outlets could be offered support to establish some form of training in either user related skills or in applications - as in Singapore;

(e) training programmes for potential users of computing systems. This is a key area now receiving attention in the OECD and by some NICs. Both programmers and senior technical/management personnel will need training. Support for such programmes could be channelled through new or existing institutions;

(f) apprenticeship schemes for personnel to be given on-the-job training with established firms. Direct subsidies to the firm would be necessary; and

(g) overseas training will be necessary for many of the skills required. For newly trained graduates, this could either be in universities for higher degrees or in specialized training institutions.

Because of the key importance of "people-to-people" technology transfer, and the need to be "in-touch" with current developments, regular overseas training visits for established personnel would be particularly valuable. This could involve a combination of work/training in university/R&D institutions as well as periods spent with firms - the latter being particularly important. An organized programme of visits/exchanges with established firms- both large and small - could be a very productive use of public sector training funds.

Section 3: Policy Issues in Computer Applications in the Public Sector

We noted in Chapter 1 that the versatility and low cost of the microcomputer has already led to its use in a wide number of what might be termed development applications. It is virtually inevitable that this process will continue and it is likely to do so at an increasing rate. For many of the poorer countries, the use of microcomputers in development projects represents one of the areas where the most immediate changes will occur. There are many pressures which will lead to a rise in the use of the microcomputer. Among the external forces, suppliers of microcomputer hardware and software searching for markets will be particularly important. IBM, for instance, has created an African Institute to foster the use of microcomputers for development, with its own Personal Computer obviously receiving priority; French firms are using the outreach programmes of the World Centre for Microelectronics to provide a conduit to get their system into use. International and bilateral agencies are also playing a key role by pressing aid recipients to use the technology for administration of projects and indeed by supporting projects with the explicit intention of introducing microcomputers. Internally, a growing array of government departments are pursuing the use of the techology as an aid to administration, planning and project implementation.

The existence of these pressures is not surprising since a priori there are likely to be many areas of application where the technology can be of aid. In addition to their use in specific projects of the sort listed in Appendix 2, microcomputers can help enormously to increase the effectiveness of government administration and to make it much less centralised and more responsive to local needs, as this quote by Schware and Trembour suggests:

> "The microcomputer could conceivably become a significant, even revolutionary tool in development efforts. In brief, using the microcomputer, provincial, district, and sub-district levels of government could begin taking over many of the tasks central ministries with their minicomputers or mainframe computers cannot - or should not - perform. The local entities could help co-ordinate activities and services provided by extension services, co-operatives, or village banks and report back to central ministries. These would then be in a position to compare the efforts, say in health services, of different districts and to get a more accurate and timely picture of activities in government levels below."
> (Schware and Trombour, 1984, pp14-15.)

Given these pressures and potential it is only logical that policies are developed to guide the introduction and use of microcomputers in development projects. It is important to note that we are not endorsing the widespread use of microcomputers in the routine clerical tasks that provide employment for so many millions of people. Our focus here is on the use of the technology in development projects where the major benefits lie in the efficient delivery of some service or product, rather than simply the saving of labour.

In this context, policies for implementation need to start from the recognition that the operating environment for microcomputers in developing countries differs greatly from that in the developed countries. In the latter, one is likely to find a high degree of competence among systems users, local production of hardware and software, availability of technical support and maintenance, software programmes written in the national language of the user, etc. In developing countries, particularly poorer countries, almost the opposite conditions will prevail. The potential user will be inexperienced, existing programmes of data collection and processing may be inefficient, decision-making may be highly centralized, etc. In addition to all these, the technical environment may be unsuitable; for instance there is often instability of electricity supply, poor quality transmission lines and various climatic factors which can adversely affect the functioning of the computer (Nolan, 1984).

The first point to make is the rather obvious one that application programmes developed for use in the developed countries will almost certainly not be directly transferable to the Third World. The areas of local application are likely to be substantially different and therefore need to be identified in a systematic manner according to development priorities. This can only be done satisfactorily by nationals of the country - not only because foreign consultants will probably only perceive a partial and biased set of applications but also because there is much long-term benefit to be gained from learning by doing. Needless to say this also goes for preparation of the applications programme and implementation of the project. Clearly both these activities have implications for training policy.

There is however much more to ensuring an appropriate operating environment than simply identifying the right applications. Microcomputers cannot be effectively introduced into a situation where existing procedures for data collection, storage and processing are not already efficiently organized. To ensure this requires a great deal of planning and preparation. Already there are numerous examples of situations where microcomputers were introduced into an unsuitable environment and were never used properly. However, there have also been successes.

Schware and Trombour (1984) cite the example of the Egyptian Health Authority which took two years of planning and preparation to facilitate the use of microcomputers for collecting and processing data on the progress of health programmes such as immunization, fertility regulation, tuberculosis and rheumatic fever control. Over these two years, studies were carried out to determine data processing requirements, skill availability, the suitability of various hardware and software configurations and so on. Following these studies, two of the chosen systems were tested under actual operating conditions; data collection personnel were trained, managers educated on the use of the system, the statistical apparatus of the Health Authority was upgraded and many other steps were taken to ensure a smooth transition to the use of the microcomputer. The actual introduction of the microcomputers into each of the 250 health districts was highly successful.

This example and other successes like it, suggest that one of the most important steps is a careful study of the organization and administrative structure in which the technology is to be applied - preferably by specialists in these areas rather than by salesmen of the hardware suppliers, as is often the case. Problems identified in the efficient functioning of the environment should be put right before designing the specific applications and introducing the system. Following this, steps must be taken to ensure that all the appropriate support and maintenance services are available locally and provided by locals. In short, care must be taken to prevent potential users from being submerged in an avalanche of technology before they are ready to use it effectively. The only way to achieve this is by the establishment and rigorous implementation of policy guidelines.

Section 4: Some General Comments on Export-Oriented Industrialization Strategies

Policies designed to promote the export of manufactured products now feature in the development strategies of developing countries at all levels of income and industrialisation. The stimulus for this shift towards an export orientation came initially from the demonstration effects of the NICs in the 1960s and 1970s. More recently, balance of payments constraints and pressures from international finance and development agencies have reinforced the urgency with which countries are pursuing the rapid expansion of their exports, either currently or as a long term objective.

The conditions in which developing countries are attempting to pursue these policies have, however, changed fundamentally in recent years. The world economy has grown more slowly in the last ten years than in the previous twenty-five; market access has become more difficult as protective barriers have risen; and international competition has become much more intense and technological in nature, particularly with the advent of microelectronics. At the broadest level, these changes in the global context confronting developing countries call into question the continued viability of export-oriented strategies which assume that the main source of Third World comparative advantage lies in low unit labour costs. The specific implications of this challenge vary for different types of country.

For those NICs and second tier developing countries whose economies are already well integrated into the international division of labour the choice is becoming clear. Either they augment their low wage advantages with a rising degree of technological competence and marketing sophistication or they risk losing their markets. It may be of course that this can be done without resorting to the use of best-practice techniques involving microelectronics - although to stay competitive Third World firms will have to continue to innovate. But at some point, particularly if the main markets are the developed countries, the more advanced developing countries will have to shift to the use of the new technology.

For those countries whose plans for export are further into the future, the costs of entry have become much higher. They will be starting far behind a technological frontier which has begun moving forward at a much more rapid rate than before. As the examples of machine tools and automobiles suggest, countries which are not already engaged in export manufacture in those sectors where the pace of technical change is high face the early prospect of being permanently shut out of the world market. The technological, financial and managerial resources required to bridge these gaps appear simply to be beyond the reach of poorer countries. The prospects are better for those sectors such as clothing where the pace of change and the diffusion of automation technology is still slow. In those cases opportunities are good for countries to build up and maintain competitive advantage based on the mastery of conventional technologies. However even there it is highly likely that in the longer term, technological barriers to entry will emerge, so that at some point Third World exporters will have to move into the use of new technology in those sectors as well.

Obviously, the greatest problems of this sort arise in exporting to the developed countries. Prospects for increasing exports of conventionally manufactured goods via South-South trade remain good once demand begins to pick up. However, the strength of the NICs will pose problems for other developing countries seeking to expand their exports. Needless to say, both groups will be under pressure from the export efforts by firms in the developed countries.

We only want here to draw some rather general conclusions about the implications of the above analysis for export-oriented strategies. In the case of the NICs and some of the second tier developing countries, their notable export performances in the 1960s and 1970s led to a reasonably well diversified and integrated industrial structure based on a degree of indigenous technological capabilities and sophisticated planning and management. The expansion of domestic demand in line with export growth was an equally important determinant of their success - and may yet prove to be a significant factor in maintaining their performance in the face of the more difficult export environment in the future. Both aspects contributed to the resilience of their economies and enhanced their capacity for rapid adjustment - allowing them, for instance, to grow their way out of the oil price-induced recession of 1974-75 and to perform reasonably well in the recent crisis. The coincidence of cheap external financing, readily accessible markets, and large unit cost differentials has probably disappeared for ever. But it would obviously be foolish to suggest that as a result, these countries should abandon their export-oriented policies for some alternative economic strategy. However, since it appears that these countries will have increasingly to adopt new technologies to survive, they should do so only on the basis of a well planned long term strategy.

For the other developing countries the pressure to move away from a blanket commitment to export led growth seems more compelling. But the likelihood of any alternative strategy leading to easy success seems equally problematic, if only because these countries will still have to deal with the domestic weaknesses that make their capacity to expand manufactured exports suspect under current conditions. Relative to the NICs, these countries are obviously less well endowed in many areas which determine their capacity to respond to external shocks. Many of these areas involve these developing countries in dependent linkages with the developed countries, which can inhibit their attainment of industrial independence and economic transformation.

Poorer developing countries are frequently characterised by an excessive degree of dependence in four areas: dependence on one or a few export products or markets; technological dependence, particularly in capital goods which are seen as important sources of indigenous innovation; managerial and entrepreneurial dependence; and foreign capital dependence.

The combined effect of these dependent linkages reduces the inherent strengths of these economies and inhibits the speed and efficiency with which they can shift resources to export sectors to earn foreign exchange. This suggests that that a major obstacle to future development is an economy's degree of external dependence. Given this, it is tempting to respond by calling for these countries to abandon any attempt at achieving growth through the expansion of manufactured exports and urge them instead to explore the possibilities of more inward-looking forms of development.

This is not the appropriate context to elaborate on the details of an inward looking development strategy except to emphasise that it need not imply the sort of autarchic isolation that seemed the logical outcome of the prescriptive analysis of the dependency and self reliance schools (Roemer, 1981). Nor should it be equated with an endorsement of the equally beleaguered era of import-substitution policies. However, policy efforts to limit or reduce those external linkages which are most damaging do seem entirely in line with the current realities of the poorer developing countries.

Section 5: Policy Issues in the Introduction and Use of MRIs in Industry

There are a wide variety of policy issues that need to be confronted regarding the aquisition and use of microelectronics-related innovations (MRIs) in industry, either within the context of export oriented sectors or for domestic production. The first set of policy concerns must be to assess the relative costs and benefits that will arise from the introduction and use of the technology. These are complicated issues that can only be judged empirically and not *a priori*. Among the broad range of factors that must be considered are not only the employment implications but the effects on international competitiveness, on market structures, on factor prices, on the nature of the skill requirements and therefore the need for training and education, on foreign exchange requirements for the acquisition of the technology and the subsequent importation of inputs and services, on infrastructure requirements in terms of power and communication, as well as maintenance and service facilities. It is simply not feasible to discuss all these issues in detail here and so we shall focus on only three.

Monitoring technical change and market structure

There is now enough evidence to suggest that most if not all sectors in which developing countries might seek to expand exports are being affected by microelectronics. As we have seen, however, the effects are uneven and the pattern of diffusion varies widely. This means that first and foremost developing countries must begin systematically to monitor the nature and scope of the changes that are occuring internationally. This is something that firms in developed countries do as a matter of course and there are numerous information networks which exist for this purpose. This practice is not so well established in the Third World and must now become a priority. There are, of course, opportunity costs involved and these must be considered - it is certain nonetheless that more efforts need to be focussed on this area.

Both governments and firms must participate in the effort. Governments can commission studies, support survey missions abroad or establish institutions or groups to collect, process and transmit information. However, firms require very specific information to assist them in making strategic decisions. Only they possess the expertise to articulate these needs and to "filter" the available information according to their specific requirements. Hence they must ultimately carry out a large share of this monitoring themselves, either individually or collectively. Such efforts are expensive however, and a programme of state subsidies can be used to defray the costs. This is probably an area where international and/or regional collaboration is called for and already some steps have been taken by the UN. The Commonwealth could play an important role here.

Obviously a wide variety of information needs to be collected on the types of technical change, the costs of technology, the effects on competitors' performance, the conditions facilitating efficient introduction and use, etc. Particular attention should be given to assessing the market conditions affecting suppliers of technology as these might be an important influence on the type of technology available and the conditions under which it will be offered. Many technology markets where MRIs are involved are likely to be highly competitive with lots of small firms involved. If technical change is rapid, or if the firms are encountering difficulties, then they may be willing to provide the technology (both hardware and software) on favourable terms, to the recipient if the latter negotiates astutely. However, the existence of these types of market conditions can only be determined through detailed analysis and study by the technology recipient. It is nevertheless a strategy that many firms in the NICs have applied successfully (see, for instance, Sercovitch (1980) and the studies reviewed in Hoffman (1983)).

Responding to systemic innovation in the North

The systemic nature of process innovation in the North, involving the integration of automation technologies, poses particular problems for developing countries. The efficient introduction of stand alone equipment such as CAD systems or CNC tools is no easy task - but can be mastered provided the appropriate conditions are present. Hence it can be argued that at least the more advanced developing countries will be able to introduce stand-alone MRIs and thereby remain competitive. However, the ongoing transition to higher forms of automation in the North poses quite another set of problems. It means that competitors who make this transformation will be reaping systems level gains much greater than those arising from the use of stand-alone equipment. Southern exporters will have to respond to this transformation even if they are still some way behind the technology frontier. However the move from using stand-alone equipment to more integrated systems of production represents a quantum jump in technological sophistication and in the financial, technical and management resources required to support the system. It is not clear how feasible it is to expect even NIC firms to be able to assimilate more highly integrated production systems. If governments and firms attempt to do so, they should be prepared for a long and costly learning period. This will inevitably involve some form of long-term state support to defray the costs of learning within the firm, to develop the necessary support facilties within the economy, and to ensure an adequate supply of skilled personnel.

Support for innovation and capability accumulation

In addition to supporting the learning process during technology transfer, governments have at their disposal a wide range of policy tools to stimulate the development of the necessary technological capabilities to efficiently utilize and improve imported MRIs. The precise forms of support depend on the types of capabilities required. In Section 2 we mentioned a wide variety of training measures which could be undertaken to increase the supply of personnel skilled in various aspects of electronics. These are also relevant in facilitating the industrial use of new technology. Here we would only once again emphasize the importance of maintaining an adequate maintenance infrastructure. This is likely to be particularly important in the poorer economies which will find that more and more imported equipment will contain electronics. No attempt should be made to import such equipment unless the requisite skills exist: governments need to take explicit steps to ensure these are available.

In most developing countries, state supported innovative activities normally take place outside the productive sector, in industrial research institutes, universities etc. Local firms operating largely within protected markets normally have little stimulus to pursue innovation and interact with the so-called formal R&D sector - they usually rely on foreign suppliers for these inputs. The activities of these institutions are therefore effectively marginalized.

In general we believe that governments in developing countries need to re-orient their R&D policies to maximize innovative effort within local firms. They can do this through subsidies, grants, fiscal incentives, secondment of research personnel, etc. However, where the use of microelectronics in product or process technology is involved, the state may have to take a more direct role in the development of capabilities and the provision of technical services to industry. This may be necessitated either by existing firms being too few or too small to carry out their own R&D or to perform other crucial services; or by the lack of certain essential services due to underdevelopment of the industry. Countries such as India, Singapore and South Korea are all promoting publicly supported technological centres in relation to the electronics sector, while organizations like UNIDO are arguing for the establishment of various other centres of excellence, multi-function software centres, etc in the Third World.

Similar initiatives could be pursued in industrial technology. For example, a "new technology centre" could be established which would serve as a "laboratory" for local firms. Such a centre could be equipped with R&D facilities that could be leased out to allow firms to develop products, skills and experience in dealing with automation technologies without undertaking the risks of using the technology for the first time. This would allow firms to internalize the knowledge gains rather than to subcontract to others (possibly foreign firms). Staff at the centre could be seconded, with industry personnel moving in and out at fixed periods. This would remove some of the problems of bureaucratization and inflexibility that always arise when new public institutions are created.

APPENDIX I: Selected Examples of Microcomputer/Microelectronics Applications

Country	Area/Sector	Nature of Application
Nigeria	Agriculture	17 microcomputers used in data collection and evaluation of surveys of smallholder farmers involved in agriculture development projects. Both agronomic and household survey carried out with direct data entry into computers.
Nepal	Family Planning and Maternal Child Health; Health Planning Units; Community Forest Development Project; Resource Conservation; Rural Development Project	18 micros used for monthly reporting; administration; project monitoring; sales and finance monitoring, socio-economic survay data analysis; payroll and personnel systems; etc
Kenya	Ministry of Agriculture and Livestock Development	Micros used in preparation of budgets and financial analyses.
Colombia	Rural energy supply	Electronic load controller for community based micro-hydroelectric systems
Sri Lanka	Urban development planning	Microcomputer based urban planning information system
Thailand	Agriculture	Microprocessor controlled sorting and quality control machines for use in rice, coffee and groundnut development projects
India	Industry	Application in information and control systems for precision engineering firms. Areas covered include direct and indirect material consumption, work-in-progress, materials with suppliers, inter-plant accounting and purchase planning.

Source: Compiled from ILO (1984) Blending of New and Traditional Technologies. Tycooly International Publishers, Dublin; various issues of Microelectronics Monitor.

APPENDIX II: Microprocessor Applications by Sector

Sector	Application	Examples
Consumer Goods	Household Domestic Appliances	Washing Machines
		Ovens
		Sewing Machines
		Safe Electronic Irons
		Smoke Detectors
		Vacuum Cleaners
		Hair Dryers
	Entertainment Products	Television Sets
		Video Games
		Video Recorders
		Hi-Fi Equipment
		Micro Computers
	Personal Products	Cameras
		Calculators
		Watches
		Electronic Notebooks
	Cars	Dashboard displays
		Engine Control
		Collision Avoidance
		Braking Systems
		Diagnostic Systems
Computers and Peripherals	Memory Equipment	Magnetic Disc/Drum Control
		Semiconductor Memories
	Input/Output Equipment	Keypunch Systems
		'Intelligent' Terminals
		Point-of-Sale Terminals
		Modems
	Data Transmission Equipment	'Front-end' Processors
		Multiplexors
Telecommunications		Public and Private Telephone Exchanges
		Telex Switching Systems
		Viewdata Terminals
Office Equipment		Word Processors
		Audio Typing Units
		Facsimile
		Electronic Mail Transmission
Retail Products	Sales	Cash Registers
		Point-of-Sale Terminals
		Inventory
		Stock Control Systems
		Material Handling Systems

Sector	Application	Examples
Banking and Insurance		Cash Dispensers Electronic Tellers Billing and Accounting Systems
Test, Measuring and Analytical Instruments	Test/Analytical Instruments	Waveform Representation Machines Oscilloscopes Fracture Investigation High and Low Frequency Fatigue Cycling Equipment
	Medical Equipment	X-Ray Scanners Ultrasound Scanners Sample Analysers Electro-oculography Tests Cardiac Arrhythmias
	Automatic Test Equipment	Microcircuit Testers
	Nuclear Equipment	Supervision of Nuclear Reactors
Industrial Control	Sequence Control	Batch Processing Control Machine Control
	Supervisory Control Systems and Administration	Process Plant Performance Achievement Monitor Labour Scheduling Production Planning Stock Control and Recording Quality Control Plant Monitoring
	Design	Computer Aided Design Computer Graphics
Military, Aerospace and Marine		Air Traffic Control Systems Radar Systems Navigation Systems Battlefield Information Computers Digital Cryptography Coding
Military, Aerospace and Marine	Bomb Disposal	Electronic Stethoscopes Explosive Detectors
	Weaponry	Remote Control Weapon Systems Precision Guided Weapons
	Communications	Direct Dial Portable Radios Marine Communications

Sector	Application	Examples
Transportation Systems	Traffic Control	Car Park Ticket Machines Traffic Flow Regulator
	Servicing	Petrol Pump Control Diagnostic Systems
	Administration	Computerised Reservations Automobile Registration
Agriculture	Cultivation and Harvesting	Potato Planter Operatorless Tractors
	Livestock Monitoring	Feed Regulators Dairy Recorders
	Remote Sensing	Weather Forcasting Pest Control
Mining and Extractive Industries	Safety	Smoke Detection Environment Control
	Extraction	Remote Control Coal Drilling Equipment
	Mineral Detection	Satellite Sensors Undersea Inspection Vehicles

APPENDIX III: Process Control Applications

Type of Plant	Nature of Applications
Cement Mixing	Process monitoring of inputs, outputs, recipe mixing, weighing, etc
Chemical	Real time process control to allow on time report 30 minutes after start-up (compared to 6 hours previously) and to allow each operation in the plant to be monitored once per second
Synthetic Fibres	Control of multi-effect evaporator for heat economy, balancing factors and preheating processes. 10 per cent energy savings achieved and total annual savings of £200,000 for £10,000 investment
Pharmaceuticals	Microprocessor based control loops in multiproduct based plants
Oil refinery	Extensive discrete control loop via microprocessors to create integrated control and supervisory system
Raw materials blending, steel rolling, paper making, power generation, food processing, distillation milling, plastics	Use of microprocessor to introduce adaptive control capability into existing systems. Allows plant to attain optimal performance under changing conditions.
Grain drying	Microcomputer based system for controlling dryer performance to ensure uniform drying
Dairy	Distributed microprocessor control units to control pasteurisers, clearing in plant washing systems (CIP), raw milk cooling, and storage
Meat Processing	Computerised recipe calculation systems designed to optimize the use of raw materials in the preparation of processed meats

Source: Compiled from Bessant 1982, various issues of Microelectronics Monitor.

APPENDIX IV: Examples of Applications in Service Sector snd Service Activities

Service	Comment
Shipping (Freight)	Substituting the shipping of printed matter by sending it through telecommunications.
Other transport (air, rail, inland waterways)	New logistic systems emerging where the goods themselves are transferred through telecommunications.
Travel (passenger transport)	The use of teleconferencing is increasingly substituting business travel for specific applications.
Tourism (councelling, advertising, tour operations, hotel/motel services)	New systems incorporating videodisc, videotext and interactive routines will become available. Hotel/motel reservations are already, as for airlines, highly computerised. Some hotels are now offering teleconferencing services between their different locations.
Insurance and reinsurance	Customers will be able to order specific insurance directly through retailing points or terminals as is now the case in many airports with flight insurance.
Banking and other financial services	Use of automatic cash teller machines providing a 24 hour service. Telebanking is done now at corporate level and experiments are being conducted in households. Internationally SWIFT will evolve into a world trading network.
Brokerage	This service is heavily based on availability of information. It will become even more international in the future when it will be possible for non-specialists to intervene through terminals thereby eliminating middle-men in many cases.
Accounting	This is one of the first applications of EDP and is used by many transnational companies on an international basis. Many small and medium sized enterprises will internalise this service rather than buy it from specialist firms.
Films and TV Features	Direct satellite broadcasting will increase transportability while the existence of video tapes will make enforcement of copyright laws practically impossible.
Wholesaling and Retailing	Easy access to price information and service could increase competition in this sector. Complex delivery systems are likely to be developed. In large super-market chains, the trend is to offer also a "super-market of services".

Service	Comment
Repairs and Maintenance	As equipment includes electronics and self-diagnosis, maintenance and interaction for repair can be done long distance as well as running recovery routines. Modular repairs are increasing the self-service aspect of this activity.
Data processing	The key in this sector is the ease of data communications. Data can be processed within or outside the country.
- Software	Software can be developed by teams at distant locations as well as maintained. It can be distributed using telecommunications lines.
- Remote data entry	There is a growing trend to use cheap skilled clerical labour for remote data entry, replacing key punch operators.
Information services - Newspapers	Newspapers are considered as "goods". However, telecommunications permits the International Herald Tribune to be edited in Paris and printed in Zurich, Paris, London and Hong Kong. In turn Videotext will partly do away with hard copies.
- On-line systems	Commodity, stock and financial information. It will develop to provide a more analytical type of format with graphics included.
Construction engineering (management, consulting, design/architecture)	The use of CAD systems and remote entry for calculations in certralised systems will increase transportability.
Professional services	Remote access is the key in this sector.

Source: Rada, 1983

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