Commonwealth Economic Papers: No 21

The Management of Technological Change

BACKGROUND PAPERS PREPARED FOR

A COMMONWEALTH WORKING GROUP

Commonwealth Secretariat

COMMONWEALTH ECONOMIC PAPERS: No. 21

THE MANAGEMENT OF TECHNOLOGICAL CHANGE

Background papers prepared for
a Commonwealth Working Group

Economic Affairs Division
Commonwealth Secretariat
Marlborough House, London SW1Y 5HX

April 1986

Printed and published by
The Commonwealth Secretariat

May be purchased from
Commonwealth Secretariat Publications
Marlborough House
London SW1Y 5HX

ISBN 0 85092 289 5

THE MANAGEMENT OF TECHNOLOGICAL CHANGE: Selected Background Papers

CONTENTS

THE MANAGEMENT OF TECHNOLOGICAL CHANGE

PREFACE

Commonwealth Heads of Government, at their meeting in New Delhi in 1983, endorsed a recommendation from Commonwealth Employment and Labour Ministers that a Commonwealth Working Group be set up to examine member countries' experience in managing technological change. The Group, which was chaired by Prof.M.G.K. Menon of India, submitted its report, "Technological Change: Enhancing the Benefits", to Commonwealth Governments in August 1985. It was made available to the wider international community during the following month, and considered at the Commonwealth Heads of Government Meeting in The Bahamas in October.

The Commonwealth Secretariat, in servicing the Group, commissioned reports and provided other documentation to help its members to fulfil their task. The Group duly examined the impact of adopting new technologies, particularly microelectronics, on the economies of Commonwealth countries, identified policies to facilitate adjustment to those technologies, and suggested arrangements for sharing Commonwealth experience to enable member countries to derive maximum benefits from new technologies.

In view of the interest in the Group's Report, it has been decided to make a selection of the background papers done for its members available to the general public.

Chapter I contains a report on "The Impact and Policy Implications of Microelectronics" by Kurt Hoffman of the Science Policy Research Unit, University of Sussex. Mr.Hoffman, who has written extensively on this subject, first surveys developments in microelectronics and considers their national and international impacts; he then reviews the nature and orientation of existing policy mechanisms towards microelectronics, and finally suggests some policy options in this respect which are available to countries at different stages of economic development. The study is directed towards the developing countries, but it necessarily draws heavily on the experience of the advanced industrial economies. Particular attention is drawn to the pervasive effects of microelectronics technology on every country's economy and society. In some areas of this technology Mr.Hoffman foresees considerable difficulties for developing countries; but in others there seem to be great opportunities. Even the present situation is in many respects unclear,however, and in a technology as dynamic as microelectronics, the future is very much an unknown quantity. Only one thing seems certain: that microelectronics technology has the potential to alter the lifestyle of all mankind, for better or for worse.

In Chapter II, N.P. Singh concentrates on the institutional framework and policy development process of technology policy formulation in developing countries. Mr.Singh, who as Secretary to the Technology Policy Implementation Committee of the Government of India is writing in a personal capacity, first surveys the present position of technology policies in a selection of Commonwealth developing countries, reviewing and then assessing these countries' policy objectives, criteria and institutional framework. The second part of his report makes suggestions for future improvements, not only in technology policies but also in related economic, social and environmental policies and in other measures.

In Chapter III, John Evans of the European Trade Union Institute, Brussels discusses employment and labour questions. The first part of Mr.Evans' paper examines the impact of technological change on employment - on its level, quality and nature, including such aspects as health and safety at the workplace; the second part considers agreements for negotiating technological change, reviewing the various interests involved and practical experiences gained, and suggesting the modalities of a model agreement.

Technology selection is vital to economic and social development, and in Chapter IV,James Pickett, Director of the David Livingstone Institute of the University of Strathclyde, examines some of the elements involved in the choice of industrial techniques in developing countries. Prof.Pickett sets out to consider whether the range of existing industrial techniques is sufficiently large and dense to enable optimal choices to be made, and in so doing discusses some aspects of the policies needed to enhance technical progress. An addendum considers the consequences of improved choice and of emerging techniques.

Chapter V also relates to the choice of industrial technologies, but this time looked at more from the standpoint of an aid agency. Written by a member of staff of the Industrial Development Unit (IDU) of the Commonwealth Fund for Technical Cooperation, the note first provides some background on the role of technology transfer in IDU-assisted projects. It then considers the criteria for selecting technologies for commercial projects in developing countries and the importance of enhancing these countries' scientific and technological capabilities. There follows a brief review of trends in world industry and of their implications for developing countries' technology. A concluding section details three cases of IDU assistance in the provision of advanced technology.

The final chapter concerns biotechnology and the third world. Written by R.N. Azad when he was Assistant Director of the Food Production and Rural Development Division of the Commonwealth Secretariat, the paper first surveys the areas of potential application of biotechnology, and its economic and social aspects. This is followed by consideration of the potential for biotechnology in developing countries and some of the policy issues involved. In a concluding passage Dr.Azad emphasises the vast potential that biotechnology holds for developing countries, and puts in a plea for greater international support to realise this potential.

On behalf of the Secretariat and the Commonwealth Working Group I would like to express my gratitude to the authors for their willing response to requests to write papers and for the useful contribution this effort made to the analyses and recommendations contained in the Group's Report.

It should be noted that the views expressed in the papers are those of the authors and do not necessarily reflect those of members of the Working Group, the Commonwealth Secretariat or Commonwealth Governments.

B. Persaud
Director and Head,
Economic Affairs Division

CHAPTER I

MANAGING TECHNOLOGICAL CHANGE IN DEVELOPING COUNTRIES:

THE IMPACT AND POLICY IMPLICATIONS OF MICROELECTRONICS

Kurt Hoffman

Science Policy Research Unit
University of Sussex.

March 1986

TABLE OF CONTENTS

LIST OF TABLES AND FIGURES

TABLES PAGE

Chapter 1

Chapter 2

PAGE

PAGE

FIGURES

Chapter 1

Chapter 2

Chapter 3

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

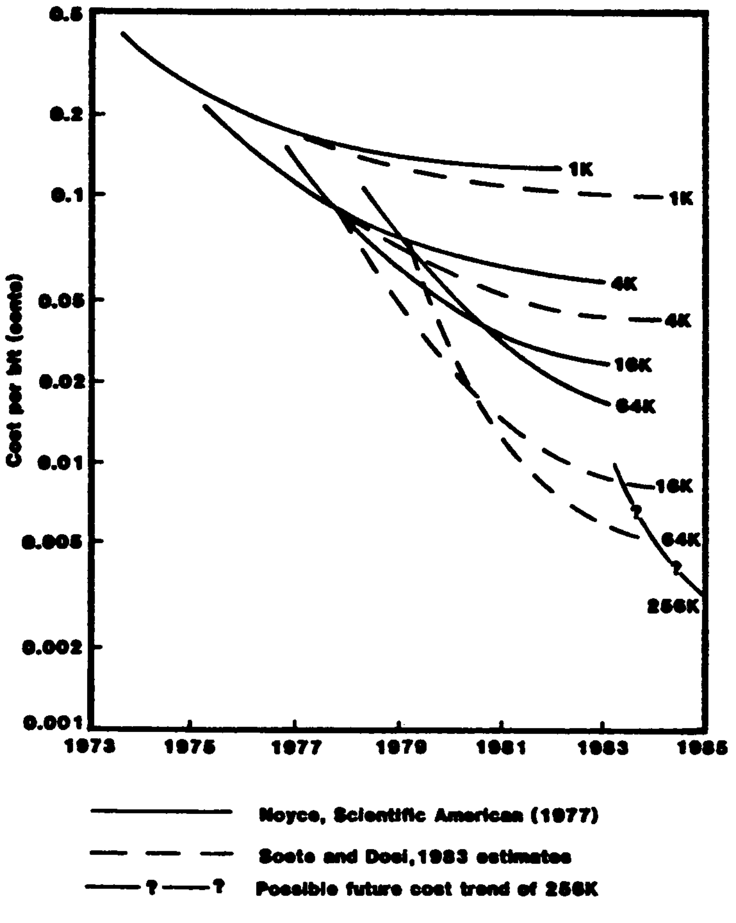
Innovation	Firm	Date of Introduction
Single crystal growing	Western Electric	1950
Oxide masking and diffusion	Western Electric	1950
Planar process	Fairchild	1960
Beam lead	Western Electric	1964
Ion implantation	Mostek	1970
Schottky junction	TI	1970
Integrated injection logic	Philips	1973
Plasma etching	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 Value ($000)	1967 % of world	1973 Value ($000)	1973 % of world	1978 Value ($000)	1978 % of world	1980 Value ($000)	1980 % of world	% annual growth rate 1970-1980
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 - Electro-medical, 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	% of developing world	Electrical Machinery	% 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.

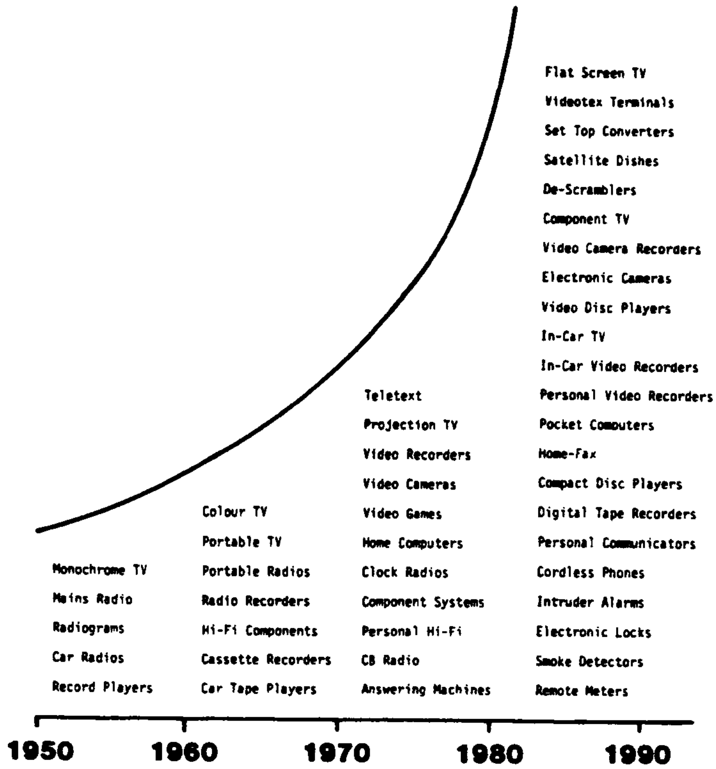
This has occurred at the same time that the range of functions has increased enormously (Rada, 1983). This same trend has also emerged in the case of colour TV sets. Mackintosh (1984) shows how as the consumer price index rose by 125 per cent over the 1975-1982 period, the price index for colour TVs 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.

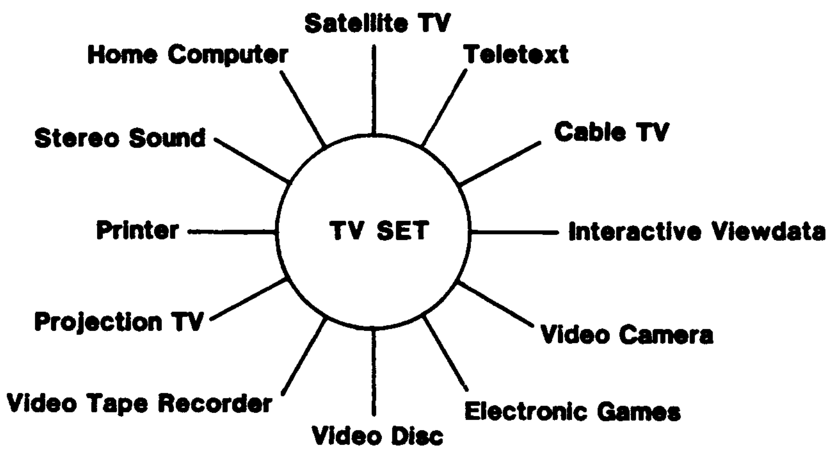
The evolution of consumer electronics products from maturity to dematurity due to microelectronics also illuminates the changing fortunes of developing countries in the electronics industry. Until recently, the assembly of consumer electronics products was highly labour intensive and for many developing 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 19[illegible].

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_i^* = 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			GHANA		
User Organisation	Type of Computer	Year of Install.	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 Engineering & Technology	IBM 370/115	1979	West Africa Exams Council	IBM	
			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 Processor	1967	SERVICES		
			Electricity (VRA)	Wang	1983
Project Implementation Bureau	IBM SYSTEM 34	1981	Electricity Corporation	Wang	1984
Population Control & Family Planning Division	IBM SYSTEM 34	1981	Water/Sewerage Corporation	Wang	1983
			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$m)	1978 A/D (%)	1978 C/D (%)	1982 Value (US$m)	1982 A/D (%)	1982 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.

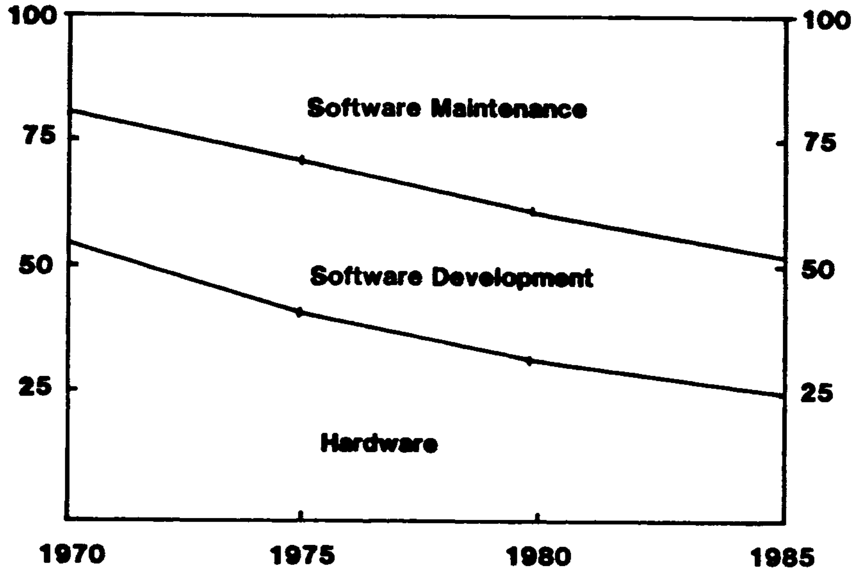
Hence the problems are largely policy issues relating to the size of the market, the role of imports, the nature of necessary government procurement and incentive policies, the selection of the appropriate point of entry and the provision of adequate supplies of trained personnel. We shall come back 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 indigenous 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 **Process Planning** *Equipment Parts Inventory *Automated Warehousing *Machine Monitoring *Manufacturing Planning	*Labour & Machine Time Standards *Machine Utilisation Analysis *Process Control **Material Management** *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	*Plant & Equipment Layout *Equipment Design **Reliability Engineering** *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	1978	Growth 1978/1970	Rankings (N = 15) Value (1978)	Growth	Draughting intensity	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.

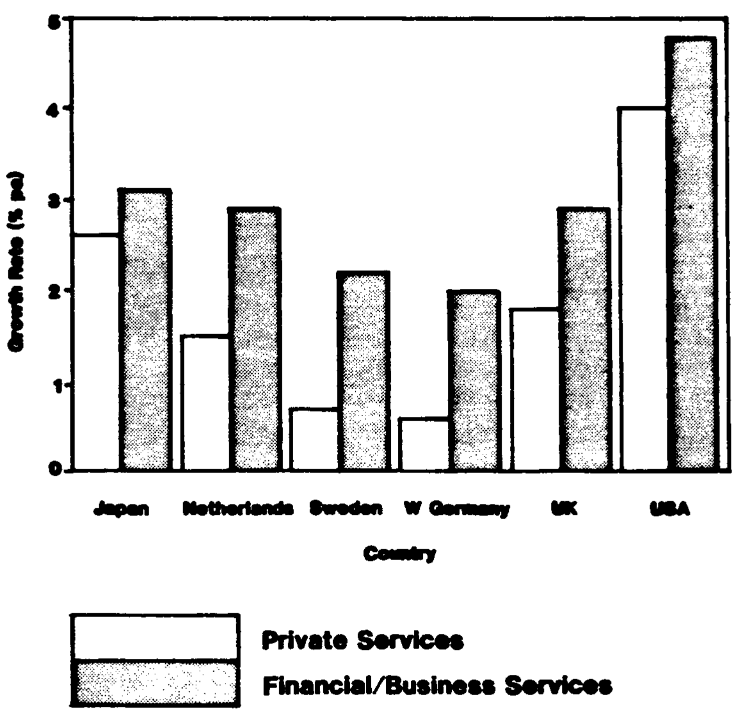
Related developments involve the dyeing process. In the late 1960s and early 1970s, both textile and electronics companies developed sophisticated sensors linked to computer control and monitoring of process parameters such as temperature, dye bath strength, etc. Previously the wide margins of error 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			Flexible machining centre
	Conventional	Stand alone NC	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

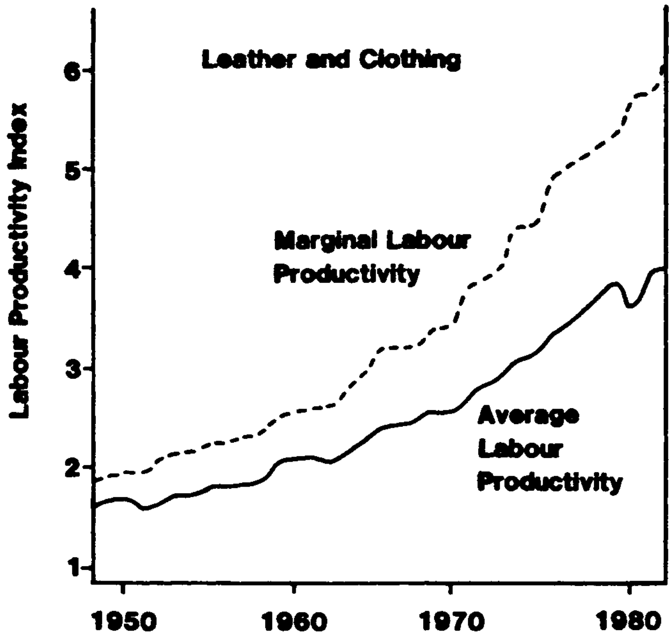
The export of clothing is an important source of foreign exchange and employment for a much wider group of developing countries (including those from the Commonwealth) than is the export of machine tools. Many smaller countries hope they can repeat the export success of the NICs, and are pursuing the 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 P	Belgium E	Denmark P	Denmark E	Germany(FR) P	Germany(FR) E	France P	France E	Italy P	Italy E	Netherlands P	Netherlands E	UK P	UK 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.

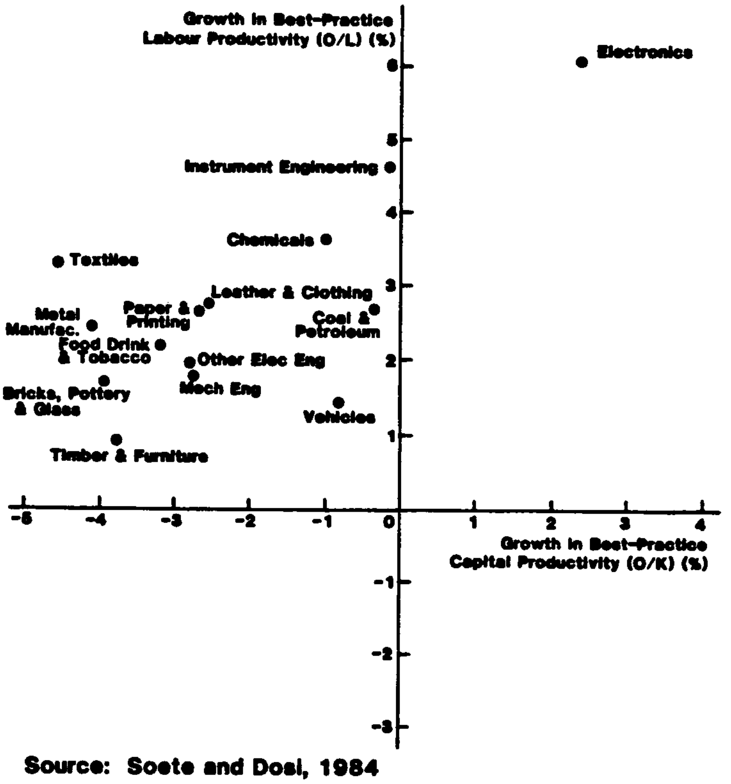
But can the diffusion of microelectronics actually have this effect? The answer depends in large part on the effects of the technology on capital as well as on labour productivity. If capital productivity rises (i.e. more output can be produced per unit of capital), then two things should happen - profits 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.

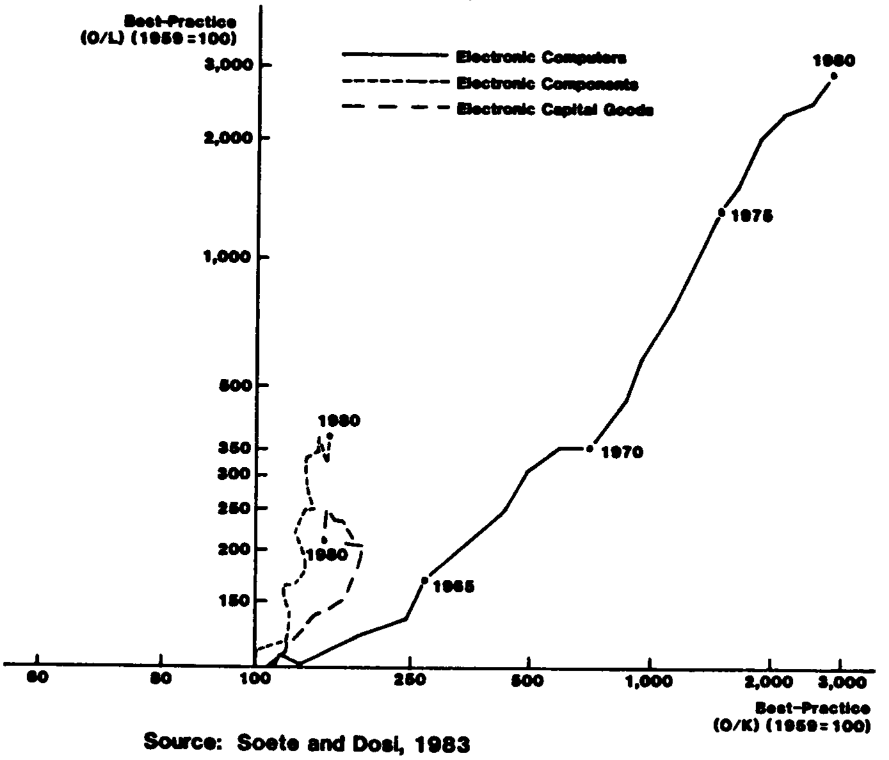
We must stress that this reasoning is highly speculative since we are relying on evidence (which could itself be criticised) from only one sector in only one economy, both of which may be atypical. However, the recent performance of the UK economy does bear a strong resemblance to a number of other European 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 tele-communications 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	Carried out within: Public corps.	Source of finance: Privately* funded	Source of finance: Public corps.	Source of finance: 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 Alērie", 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	1977	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.
	Permanent Secretariat for Informatics	1982	
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 productive 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 technological 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 thingsor 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 <u>within</u> 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

APPENDIX V: BIBLIOGRAPHY

AGARWAL, S.B. (1985) "Electronics in India: Past Strategies and Future Possibilities", in K. Hoffman (ed) Microelectronics, International Competition and Development Strategies: the Unavoidable Issues. Special Issue of World Development, January 1985.

ARNOLD, E. and SENKER P. (1982) Designing the future. The Implications of CAD Interactive Graphics for Employment and Skills in the British Engineering Industry. Science Policy Research Unit, University of Sussex, UK.

AYRES, S. and MILLER, S. (1984) "An Exploratory Assessment of Second Generation Robotics and Sensor-Based Systems". Mimeo. Engineering and Public Policy, Carnegie-Mellon University, Pittsburgh.

AYERS, S. and MILLER, S. (1983) Robotics: Applications and Social Implications. Ballinger Publishing Company, Cambridge, Mass.

BALASSA, B. (1980) "The Process of Industrial Development and Alternative Development Strategies". World Bank Staff Working Paper No. 438, IBRD, Washington.

BARRAS, R. (1984) "The Case Of Office-Based Systems". OECD Department of Science, Technology and Industry. DSTI/ICCP/84.11 Paris.

BESSANT, J. (1982) Microprocessors in the Production Process, Policy Studies Institute, London.

BESSANT, J. (1983) "Technology and Market Trends in the Production and Application of Information Technology". Microelectronics Monitor Dec. 1983, UNIDO, Vienna.

BLS-PEDDLER LTD (1982) UK Annual Census of Information Processing Systems. BLS-Peddler Ltd, London.

BUSINESS WEEK (1981) "The Speed Up in Automation". Business Week.

CHEONG, K.C. and LIM, L.Y.C. (1981) "The Electronics Industry in Malaysia: Issues in Transfer and Development of Technology". Asian Economies Dec. 1981, No. 39.

CHUDNOVSKY, D. (1984) "The Diffusion of Electronics Technology in Developing Countries' Capital Goods Sector: The Argentinian Case". CET/IPAL Report; Buenos Aires, June 1984.

CHUDNOVSKY, D., NAGAO, M., JACOBSSON, S. (1983) Capital Goods Production in the Third World. Francis Pinter, London.

CLARK, J. and CABLE, V. (1982) "The Asian Electronics Industry Looks to the Future" in R. Kaplinsky (ed) Comparative Advantage in an Automating World. IDS Bulletin, University of Sussex, March 1982.

COMMONWEALTH SECRETARIAT (1982) Protectionism: threat to international order; the impact on developing countries. Report by a Group of Experts. London.

CONNORS, S. and GARNER, R. (1981) "Robots". Computing, October 29, 1981

COOPER, C.M. and CLARK J.A.C. (1982) Employment, Economics and Technology: the Impact of Technological Change on the Labour Market. Wheatsheaf Books, Brighton.

CORNWALL, J. (1977) Modern Capitalism: Its Growth and Transformation. Martin Robertson, London.

DE BANDT, J. (1981) "Policy Reponses of the Developed Countries", in Renshaw (ed), op. cit.

DELAPIERRE, M., MICHEL, C.A. and ZIMMERMANN, J.B. (1983) "Transnational Corporations in the International Computer and Data Processing Industry". Report submitted to UN Centre on Transnational Corporations, New York.

DENNISON, E.F. (1979) "Explanations of Declining Productivity Growth". Survey of Current Business, August, Vol. 59, No. 8.

DOSI, G. (1981) "Institutions and Markets in High Technology Industries: An Assessment of Government Intervention in European Microelectronics", in C. Carter (ed) Industrial Policies and Innovation. Heinemann, London.

EDQUIST, C. and JACOBSSON, S. (1984) Trends in the Diffusion of Electronics Technology in the Capital Goods Sector. Research Policy Institute, University of Lund, Sweden.

ELECTRONICS WEEK (1984) "World Markets show renewed vigour as US leads the way". Electronics Week, July 23, 1984.

ERNST, D. (1983) The Global Race in Microelectronics: Innovation and Corporate Strategies in a Period of Crisis. M.I.T. Press, Cambridge, Mass.

ERNST, D. (1985) "Automation and the Worldwide Restructuring of the Electronics Industry - Strategic Implications for Developing Countries", in K. Hoffman (ed) op. cit.

EUROPEAN TRADE UNION INSTITUTE (1984) European Industrial Policy for the Electronics and Information Technology Sector. E.T.U.I., Brussels.

EUROPEAN TRADE UNION INSTITUTE (1979) The Impact of Microelectronics on Employment in the 1980's. E.T.U.I., Brussels.

FINANCIAL TIMES (1983) October 26.

FRANK, W.L. (1984) Critical Issues in Software. John Wiley & Sons, New York.

FREEMAN, C. (1983) "The New Economic Context". Mimeo. Science Policy Research Unit, University of Sussex, UK.

FREEMAN, C. (1979) "Technical Change and Unemployment" in S. Encel and J. Ronayne (eds), Science, Technology and International Perspectives. Pergamon, London.

FREEMAN, C., CLARK, J., SOETE, L., (1982) Unemployment and Technical Innovation: A Study of Long Waves and Economic Development. Francis Pinter, London.

GODFREY, M. (1983) "Export-Orientation and Structural Adjustment in Sub-Sahara Africa", in Allison, C. and Green, R. (eds) Accelerated Development in Sub-Sahara Africa. IDS Bulletin, Vol.14, No.1.

GOMULKA, S. (1971) Inventive Activity, Diffusion and the Stages of Economic Growth. Aarhus University, Institute of Economics, Paper No. 24.

GOVERNMENT OF INDIA (1979a) Report of the Review Committee on Electronics. New Delhi.

GOVERNMENT OF INDIA (1979b) Report of the Departmental Working Group on Electronic Components. Department of Electronics, New Delhi.

GUNN, T.G. (1982) "The Mechanisation of Design and Manufacturing". Scientfic American, Vol. 247, No.3, September 1982.

HALLIBURTON, J. (1980) "Potential Advantages to the Apparel Industry of Automated Piece Goods Inspections". Mimeo. Georgia Institute of Technology, Atlanta, Georgia.

HATVANY, J., MERCHANT, M.E., RATHMILL, K., YOSHIHAWA, H. (1981) Results of a world survey of computer-aided manufacturing. National Academy of Sciences, Washington DC.

HINES, C. and SEARLE, G. (1979) Automatic Unemployment. Earth Resources Research, London.

HOFFMAN, K. (1982) "Job Creation and Microelectronics-Based Technical Change: The Role of Software". Mimeo. Science Policy Research Unit, University of Sussex, UK.

HOFFMAN, K. (1981) "Third World Industrialisation Strategies in a Restructuring World Economy" UNIDO Global and Conceptual Studies Branch, Working Paper. Vienna.

HOFFMAN, K. and RUSH, H. (1986) Microelectronics and Clothing: The Impact of Technical Change on a Global Industry. Praeger Pub., London and New York (Forthcoming).

HOFFMAN, K. and RUSH, H. (1980) "Microelectronics, Industry and the Third World". Futures, August.

IBI (1980) Microinformatics in the 1980s. Documents on Policies for Informatics, SPIN231, Rome.

JACOBSSON, S. (1982) "Electronics and the technology gap - the case of numerically controlled machine tools". In Kaplinsky R., Comparative advantage in an automating world. IDS Bulletin, March 1982, Vol. 13, No.2.

JACOBSSON, S. (1985) "Technical Change and Industrial Policy - The Case of Computer Numerical Controlled Lathes in Argentina, Korea and Taiwan", in K. Hoffman (ed) op. cit.

JENKINS, C. and SHERMAN, B. (1979) The Collapse of Work. Eyre Methuen, London.

JONES, D.T. and WOMACK, J. (1985) "Developing Countries and the Future of the Automobile Industry", in K. Hoffman (ed) op. cit.

KAPLINSKY, R. (1984) Automation: the technology and society. Longmans Publishing Co, London.

KAPLINSKY, R. (1982) Computer-Aided Design, Electronics, Comparative Advantage and Development. Francis Pinter, London.

KAPLINSKY, R. (1985) "Electronics-Based Automation and the Onset of Systemofacture: Some Implications for Third World Industrialization", in K. Hoffman (ed) op.cit.

KAPLINSKY, R. (1981) "Radical Technical Change and Manufactured Export Growth Strategies". Vierteljahresberichte der Entwicklung Hardenforshung, March.

LALL, S. (1980) "Developing Countries as Exporters of Industrial Technology". Research Policy, Vol. 9.

LAMBERT, R. (1983) "Geared for a Real Revival: General Electric in the US goes for a major investment". Financial Times, 14 April.

LEE, CHONG OUK (1983) "A Note on Semi-Conductor and Computer Industry in Korea". Mimeo. Korea Advanced Institute of Science and Technology, Seoul, Dec. 1983.

MACKINTOSH INTERNATIONAL (1984) "The European Consumer Electronics Industry: A Presentation to the EEC". Mackintosh International, London, May 1984.

MACKINTOSH INTERNATIONAL (1980) "An Overview of the Electronics Industry in Europe." Mackintosh International, London.

MADDISON, A. (1979) "Long Run Dynamics of Productivity Growth". Banco Nazionale del Lavoro Quarterly Review No. 128, March pp 3-44.

MALAYSIAN BUSINESS (1984) "Cycle of Fortunes". Malaysian Business August 1984.

MAXWELL, P. (1983) "Specialization Decisions in Electronic Production - Lessons from the Experience of Two Argentine Firms", in S Jacobsson and J. Sigurdson (eds) Technological Trends and Challenges in Electronics. University of Lund, Sweden.

MICROELECTRONICS MONITOR Various issues (1982-1984). UNIDO, Technology Division, Vienna.

MONASINGHE, M, DOW, M. and FRITZ, J.(1985) Microcomputers for Development: Issues and Policy. National Academy of Sciences, Washington, D.C. 1985

NARASIMHAN, R. (1984) "Guidelines for Software Development in Developing Countries". UNIDO/IS 439, Vienna.

NEDO (1981) , NEDO/EDC. London, October 1981.

NEDO (1980) "UK Competitors Official Policies towards the Electronics Industries". NEDO, London, Dec. 1980.

NOCHTIEFF, H. and LAHERA, E. (1982) "Microelectronics and the Development of Latin American Problems and Possibilities for Action". UNIDO, Vienna, August 1982.

NOLAN, R. (1983) "Informatics for Industrial Development". UNIDO/IS 75, Technology Division, Vienna.

NOYCE, R. (1977) "Microelectronics". Scientific American, Vol 237 No.3, September.

O'CONNOR, D. (1983) "Global Trends in Microelectronics: Implications for Developing Countries". Paper prepared for the World Bank, Electronics, Telecommunications and New Technology Division, Washington, D.C.

O'CONNOR, D.(1985) "The Computer Industry in the Third World: Policy Options and Constraints", in K. Hoffman (ed) op. cit.

O'CONNOR, D. (1983) "Transnational Corporations in the Semi-Conductor Industry". UN Centre on Transnational Corporations, New York.

OECD (1970) Gaps in Technology Analytical Report and Sector Studies. OECD, Paris.

OECD (1980) Technical Change and Economic Policy: Science and Technology in the New Economic and Social Context. OECD, Paris.

PATEL, P. and SOETE, L. (1984) "Information Technologies and the Rate and Directions of Technical Change". OECD DSTI/ICCP/84.20, Paris, May 1984.

PAVITT, K and SOETE, L. (1981) "International Differences in Economic Growth and the International Location of Innovations", paper prepared for Kiel Symposium on Emerging Technology: Consequences for Economic Growth, Structural Change, and Employment in Advanced Open Economies, June 1981.

PEREZ, C. (1985) "Microelectronics, Long Waves and World Structural Change: New Perspectives for Developing Countries", in K. Hoffman (ed) op. cit.

PIERCE, F. (1981) "and Man Made Robot", CAD/CAM International, October.

RADA, J. (1983) International Division of Labour and Technology. International Institute of Management, Geneva, September.

REMPP, H. (1982) Introduction of CNC machine tools and flexible manufacturing systems: economic and social impact. Paper delivered to the Seminar on European Employment and Technological Change, Rome, February 10-12, 1982.

RENSHAW, C. (ed) (1981) Employment, Trade and North-South Co-operation. I.L.O., Geneva.

ROSENBERG, N. and FRISCHTAK, C. (1983) "Technological Innovation and Long Waves". American Economic Review: Papers and Proceedings, May 1983.

ROSENBROCK, H. (1983) "Designing Automated Systems - Need Skills be Lost?" Paper submitted to BAS 1983 meeting, University of Sussex, August 1983.

ROTHWELL, R. (1981) "Non-price factors in the Export Competitiveness of Agricultural Engineering Products. Research Policy 10 (81).

RUSH, H. and SOCLE, L.(1984) "Clothing" in Technical Trends and Employment; Basic Consumer Goods (ed) K. Guy, Gower, London.

SCHWARE, R. and TROMBOUR, A. (1984) "Back to Basics: Rethinking Microcomputer Technology Transfer to Developing Countries". Mimeo. Boulder, Colorado.

SENKER, R. (1983) "Engineering Skills in the Robot Age". Mimeo. Science Policy Research Unit, University of Sussex, UK.

SENKER, P. (1981) "Technical Change, Employment and International Competition". Futures, June.

SERCORITCH, F. (1980) "State Owned Enterprises and Dynamic Corporative Advantages in the World Petrochemical Industry: The Case of Commodity Olefins in Brazil". Harvard Institute for International Development, Discussion Paper No. 97.

SHAIKEN, H. (1980) Computer Technology and the Relations of Power in the Workplace. International Institute for Comparative Social Research, Discussion Paper No 80-127, Berlin.

SIGURDSON, J. (1983)"Forces of Technological Change" in S Jacobsson and J Sigurdson (eds) Technological Trends and Challenges in Electronics. University of Lund, Lund, Sweden, pp1-30.

SOETE, L. (1985) "Electronics", in L. Soete (ed) Technological Trends and Employment: (3) Electronics and Communication. Gower, London.

SOETE, L. (1981) " A General Test of Technological Gap Trade Theory". Mimeo. Science Policy Research Unit, University of Sussex, February.

SOETE, L. (1980) "The Impact of Technological Innovations on International Trade Patterns: the Evidence Reconsidered". Paper prepared for OECD Science and Technology Indicators Conference, September, Paris.

SOETE, L. (1985) "International Diffusion of Technology, Industrial Development and Technological Leapfrogging", in K. Hoffman (ed) op.cit.

SOETE, L. (1981b) "Technical Change, Catching Up and the Productivity Slowdown. Mimeo. Science Policy Research Unit, University of Sussex, UK.

SOETE, L. and G. DOSI (1983) Technology and Employment in the Electronics Industry. Francis Pinter, London.

SOETE, L. and FREEMAN, C. (1984) New Technologies, Investment and Employment Growth. OECD/DSTI Intergovernmental Conference on Employment Growth in the Context of Structural Change. February 1984, Paris.

STENMER and FERREIRA (1983) "CAM in Brazil". Conference on International CAD/CAM, UNIDO, Cordoba, 1983.

TIGRE, P.B. (1983) Technology and Competition in the Brazilian Computer Industry. Francis Pinter, London.

UNITED NATIONS (1983) World Economic Survey: Current Trends and Policies in the World Economy. UN, New York.

UNCTAD (1983) "Protectionism and Structural Adjustment - Production and Trade in Services: policies and their underlying factors bearing upon international service transactions". UNCTAD, Geneva.

UNIDO (1984) Industry in a Changing World. UNIDO, Vienna.

WATANABE, S. (1984) "Market Structure, Industrial Organisation and Technological Development: The case of the Japanese electronics-based NC-machine tool industry". Technology and Employment Programme, ILO, Geneva, WEP 2-22/WPIII.

WERNECKE, D. (1983) Microelectronics and office jobs: The impact of the chip on women's employment. ILO, Geneva.

WILLIAMS, E. (1982) "Switzerland survives - at a price". Financial Times, October 26 1982.

WILLS, R.M. (1983) "Software Policies for the Developing World". IDRC, Ottawa, September 1983.

WILSON, R.A. (1984) "Information Technology and Economic Perspectives: Intra-Industry Analysis (Future Perspectives) - Engineering", OECD, DSTI/ICCP/84.13, Paris, May 1984.

CHAPTER II

TECHNOLOGY POLICY FORMULATION IN DEVELOPING COUNTRIES:

with special reference to

Institutional Framework and Policy Development Process

N.P. Singh

New Delhi,
October 1985

The views expressed and the suggestions made in this report are those of the author. They do not necessarily represent those of the Commonwealth Secretariat or of the Government of India, by whom the author is employed as Secretary to the Technology Policy Implementation Committee.

TECHNOLOGY POLICY FORMULATION IN DEVELOPING COUNTRIES

Contents

INTRODUCTION

This is an abridged and updated version of a report originally commissioned by the Commonwealth Secretariat in October 1984 to provide background material for members of the Commonwealth Working Group on the Management of Technological Change.

The report is in two parts. The first part defines certain terms and sets out the geographical coverage of the report. It then briefly surveys present policies and related institutional frameworks for promoting and facilitating technological change in selected Commonwealth countries at different stages of economic development. The second part looks to the future and discusses possible improvements to technology policies and other measures in order to enhance their operational efficacy in helping to fulfil the overall socio-economic goals of communities.

Because of time and other constraints the report had to be based on literature available within India. But bearing in mind the relative lack of development of science and technology policies in most countries, it is doubtful if a wider survey would have made a very great difference to the outcome of the report.

The author wishes to express his appreciation to the authorities concerned at the Planning Commission, Department of Science and Technology, Council of Scientific and Industrial Research, National Council of Applied Economic Research, NISTADS, United Nations, IDRC, British Council and other institutions in New Delhi for the library facilities availed to him. He is also grateful to Professor M.G.K. Menon, Member, Planning Commission and Chairman, Technology Policy Implementation Committee, Government of India, for guidance in preparing the report and to the Commonwealth Secretariat for entrusting him with the task. Finally, the author wishes to emphasise that all views expressed and suggestions made in the report are his own and do not necessarily represent those of the Technology Policy Implementation Committee or the Cabinet Secretariat of the Government of India, nor those of the Commonwealth Secretariat.

Part I

TECHNOLOGY POLICIES AND ECONOMIC AND SOCIAL DEVELOPMENT : THE PRESENT POSITION

Section 1

Definitions and Coverage

Definitions

The literature on science and technology (S&T) policy makes frequent use of certain expressions or phrases. Some of these are useful in the context of the present report and are defined below.

(i) "Science" can be considered as a systematic study aimed at the basic understanding of natural or social phenomena and the unravelling of cause and effect relationships involved.

(ii) "Technology" is defined in Webster's Seventh New Collegiate Dictionary as "a technical method of achieving a practical purpose" and "the totality of the means employed to provide objects necessary for human sustenance and comfort".

(iii) "Appropriate technology" has been defined by the UNIDO Second Consultative Group on Appropriate Technology as "that technology which contributes most to the economic, social and environmental objectives of development".

(iv) "Technological change" is defined by UNCTAD[(1)] as "an advance in knowledge and a change in technique, an alteration in the character of the equipment, product and organisation, which is actually being utilised". An alternative way of looking at technological change would be from the point of view of the changes which the introduction of a new technology brings about in a society. Some of these may be substantial, in terms both of economic well-being and of social or cultural values. In this sense,technological change would be the end-result of introducing a new technology into a society.

(v) "Science and technology (S&T) policy" most commonly refers not only to policies for developing S&T itself but more especially to policies designed to ensure that the development or application of technology fulfils pre-determined socio-economic or other goals of a community. According to that definition, the objectives of a country's S&T policy would have to be derived from its socio-economic, security or other goals which, in turn, might depend to some extent on the geo-political setting of the country.

(vi) "Absorption of technology" is generally used in connection with the acquisition of technology. It implies not only understanding and mastering the operational 'know-how' of processes and techniques, but also of attempting to understand and acquire the 'know-why' of the designs, techniques and processes relating to the operations involved, with the object of being able to alter them to suit local conditions and to make further improvements to them.

(vii) "Adaptation of technology" involves making imported technologies suitable for local materials, skills and markets.

(viii) "Technology assessment", as defined by one UN organisation, is a "process for the systematic analysis, forecasting and evaluation of a broad range of impacts on society pertaining to technological change and choice in order to identify public policy and options. It helps to match technological development to national goals".[2]

(ix) "Technology forecasting" has been defined by Martino[3] as "a prediction of the future characteristics of useful machines, procedures or techniques".

There are numerous other phrases like "applied research", "basic research", "research, design and development (RD&D)", which are frequently used in the literature. Most of these are defined in the "Frascati Manual"[4]: in other cases, their meanings are obvious from the context in which they are used.

<u>Coverage</u>

This first part of the report provides a brief overview of the state of S&T policies in four Commonwealth countries at varying stages of economic development. It concentrates on technology assessment, choice, transfer, adaptation, development and utilisation, and to the structural changes and adjustments needed within and between economies and societies in order to promote and facilitate technological change. The aim is to compare and contrast the evolution of S&T policy in the four countries, to examine the objectives and criteria used in determining those policies, and to evaluate the institutional framework for their implementation. This is followed by an assessment of the efficacy of S&T policies in these countries. Drawing on these experiences, the second part of the report presents a set of model policies, at both macro- and micro-levels, which could promote and facilitate technological change.

The selected countries are India, Bangladesh, Singapore and Tanzania, particular emphasis being given to India. They were chosen primarily because of their different economic and social characteristics - reflected in their diverse levels of per capita income (ranging from US$120 in Bangladesh to US$3,770 in Singapore) as well as in their different economic sizes and structures. Singapore, as a newly industrialising country, was selected to see how far its technology policies contrasted with those of the other three.

In three of the four countries (the exception was India), the absence of field visits and the non-availability of up-to-date documents on their technology policies meant that the survey of these countries' S&T policies and institutional mechanisms was largely based on their papers prepared for the United Nations Conference on Science & Technology for Development (UNCSTD) held in Vienna in August 1979. In addition, use was made of a 1982 UNCTAD report entitled "Technology Policy in the United Republic of Tanzania : Survey of Issues and Recommendations for Action".[5]

Section 2

Objectives of S&T Policies and Criteria for Determination

As already mentioned, the objectives of national S&T policies should be decided in the light of a country's socio-economic and other goals and its geo-political setting. It should also be possible for countries to agree internationally on certain common objectives, such as the development of technologies to satisfy basic human needs. Unless S&T policies have well defined objectives both at the national and the international level it is likely that the development of new technologies will continue to be determined largely by 'market-pull'. As a large part of the world's population is too poor for their basic needs to be adequately reflected in the form of 'market demands', technological developments, left to their natural forces, generally fail to satisfy these needs, particularly of people living in developing countries. It is therefore imperative that these countries define their S&T policies with clear objectives and priorities determined in the light of their socio-economic and other developmental goals.

Since the beginning of the 1970s many developing countries, both within the Commonwealth and outside, have recognised this need. India, however, seems to be one of the few which has made an explicit statement of its S&T policy in recent years. In most other countries there is an implicit S&T policy, which can be derived from their decisions, practices and mechanisms relating to technology imports, technology development, sectoral allocation of resources for R&D, diffusion policies, labour and manpower development policies, and socio-economic goals. Bangladesh, Singapore and Tanzania all fall into this category.

The present section surveys the objectives of the explicit/implicit technology policies in these four countries. It focuses on the policy development process in terms of the assessment, choice, transfer and absorption/ adaptation of imported technologies, the development and utilisation of indigenous technologies, and the structural adjustments needed to promote technological change. The institutional framework adopted by these countries for implementing their S&T policies, e.g. for the regulation of technology imports, technology development and technology diffusion, is described later (page 175).

INDIA

Evolution of science & technology policy

One of the earliest official documents on S&T in India was the Government of India's Scientific Policy Resolution (SPR) of March 1958. This set out the major aims of the Government's S&T policy as follows:

(i) to foster, promote and sustain, by all appropriate means, the cultivation of science, and scientific research in all its aspects - pure, applied and educational;

(ii) to ensure an adequate supply, within the country, of research scientists of the highest quality and to recognise their work as an important component of the strength of the nation;

(iii) to encourage and initiate, with all possible speed, programmes for the training of scientific and technical personnel, on a scale adequate to fulfil the country's needs in science and education, agriculture and industry and defence;

(iv) to ensure that the creative talent of men and women is encouraged and finds full scope in scientific activity;

(v) to encourage individual initiative for the acquisition and dissemination of knowledge, and for the discovery of new knowledge, in an atmosphere of academic freedom; and

(vi) in general, to secure for the people of the country, all the benefits that can accrue from the acquisition and application of scientific knowledge.

Since 1958 scientific activity in India has expanded considerably. India now has a substantial infrastructure of S&T institutions and capabilities in a wide variety of fields including agriculture, health, defence, atomic energy, space, oceanography, electronics and various industries.

The second important document on S&T policy was produced by the National Committee on Science and Technology (NCST) in connection with the formulation of the first S&T Plan for India. An Approach to the Science & Technology Plan (January 1973)[6]. dealt with the contemporary status of S&T policy in India, the strategy for S&T in national development, areas of prime importance for India in S&T planning, as well as other issues related to organisational and managerial reforms and finance. One of the document's suggestions was that the public and private sectors should be encouraged to use indigenous sources of technology. It also urged the Government to draw up an S&T policy with a commitment to use all public policy instruments to promote national enterprises whose control lay in Indian hands, and to direct policy choices to the use of domestic natural and human resources even if this involved short-term costs. The report further suggested that to be really effective, a technology policy statement should cover such diverse subjects as the development and regulation of industry; the pricing of capital; the lending policies of public financial institutions; the relative pricing of indigenous and imported raw materials and intermediates; and the regulation of brand-names and patents, industrial standards and technical and commercial guarantees. Finally, it was suggested that the general thrust of the S&T Plan should be to motivate the nation to follow the 'swadeshi' (self-reliance) road and to bring about the changes needed to make the use of domestic industrial technology more attractive for public or private entrepreneurs.

Technology policy statement

In keeping with the suggestions in the NCST document, the Government produced a 'Technology Policy Statement' (TPS) in January 1983[7]. This defines the basic objective of India's S&T policy as the development of indigenous technology and efficient absorption and adaptation of imported technology appropriate to national priorities and resources. These broad objectives have been divided into various aims as follows:

(i) to attain technological competence and self-reliance, reducing vulnerability, particularly in strategic and critical areas, and making the maximum use of indigenous resources;

(ii) to provide the maximum gainful and satisfying employment to all strata of society, particularly women and the weaker sections of society;

(iii) to use traditional skills and capabilities, making them commercially competitive;

(iv) to ensure the correct mix between mass production technologies and production by the masses;

(v) to ensure maximum development with minimum capital outlay;

(vi) to identify obsolescence of technology in use and arrange for its modernisation;

(vii) to develop internationally competitive technologies, particularly those with export potential;

(viii) to improve production through greater efficiency and fuller utilisation of existing capabilities, and enhanced quality and reliability of performance and output;

(ix) to reduce the demand for energy, particularly from non-renewable sources;

(x) to ensure harmony with the environment, preserve the ecological balance and improve the quality of the habitat; and

(xi) to recycle waste materials and make full utilisation of by-products.

Priority areas for technology development identified in the TPS are:

(i) agriculture, including dry-land farming;

(ii) optimum use of water resources, increased production of pulses and oilseeds;

(iii) provision of drinking water in rural areas, improvement of nutrition, rapid reduction in the incidence of blindness, eradication of the major communicable diseases (such as leprosy and tuberculosis), and population stabilization;

(iv) low-cost housing;

(v) development and use of renewable non-conventional sources of energy; and

(vi) industrial development.

<u>Technology import policy</u>

While recognising that a policy directed towards technological self-reliance does not imply technological self-sufficiency, the TPS emphasises that imports of technology shall not be at the expense of the national interest and that indigenous initiative must receive due recognition and support. It states that in the acquisition of technology, consideration will be given to the choice and sources of technology, alternative means of acquiring it, its role in meeting a major felt need, relevance of the products, costs, and related conditions. It is further stated that where the import of technology is contemplated, the level to which technology has been developed, or is in current use, within the country, shall first be evaluated. Lists of technologies that have been adequately developed to the extent that imports are unnecessary shall be prepared and periodically updated. In such areas, no import of technology shall normally be permitted and the onus will be on the seeker of foreign technology to demonstrate that imports are necessary. An acceptable case, for instance, may be where the technology does not exist in India and the time taken to generate it indigenously would delay the achievement of development targets. The Government may identify areas of high national priority, in respect of which procedures would be simplified to ensure timely acquisition of the required technology: where such imports are allowed, importers are required to take measures to ensure that the imported know-how is absorbed, adapted and developed.

Unpackaging of technology

The TPS also suggests that as the total package of (imported) technology required for any purpose can be broken down into several components. Some of these may be readily available or indigenously developed and others may need to be imported. It is necessary to evolve norms and guidelines for such unpackaging of technology, with a view to maximising the use of domestic technological capabilities and reducing expenditure of foreign exchange on unnecessary technology imports.

Technology assessment and choice

The TPS stipulates that the existing technology assessment systems will be reviewed and that a mechanism consisting of competent groups will render advice in all cases of technology import relating to highly sophisticated technology, large investments, and national security. It further suggests that while assessing a technology for purposes of import, aspects of employment, energy, efficiency and environment will be kept in view. Further detailed guidelines for technology assessment were being evolved in October 1985.

Absorption and adaptation of imported know-how

The TPS stipulates that investment in indigenous R&D should be on an adequate scale for the absorption, adaptation, improvement and generation of new technology. While mechanisms for ensuring the meaningful absorption and adaptation of imported technology are currently being developed, many Indian enterprises are already devoting a substantial part of their R&D expenditure to the absorption of know-how, adaptive research and similar 'defensive' R&D activities.

Role of foreign capital

Foreign investment in India is generally permitted only if it brings sophisticated technology or is intended for export-oriented projects. However, there are two exceptions: first, under the Foreign Exchange Regulation Act, equity investments of up to 40 per cent of the total are permitted in priority and export sectors. Secondly, liberalised facilities have been provided for non-resident Indians making portfolio investments in India. Foreign investment up to 74 per cent of the total is also permitted in cases where the technology is highly sophisticated or is oligopolistically held and up to 100 per cent where the project is wholly export-oriented.

Guidelines for foreign collaboration

The government has laid down comprehensive guidelines for foreign collaboration[8]. The duration of foreign collaborations is, ordinarily, restricted to eight years from the date of the agreement. The payment of royalties to the collaborators is normally permitted for five years from the date of starting commercial production, although in exceptional cases up to ten years has been approved. Royalties and other fees to foreign collaborators for know-how are ordinarily restricted to 5 per cent of domestic sales, but rates of up to 7 per cent or more are considered for export-oriented projects. Where royalty and lump sum payments go together, the guidelines require the total payment to the collaborator to be restricted to 8 per cent of the value of production for a base period of five years, although higher limits have been allowed in special cases. The guidelines specifically restrict the incorporation in foreign collaboration agreements of any clauses which prevent the use of know-how or technical information for the manufacture of the products in question by the licensee on expiry of the agreement. Likewise, clauses requiring the licensee not to disclose the information in his possession to third parties after the term of the agreement are not allowed. Clauses requiring the technology purchaser to acquire machinery, equipment, materials, components or services only from the licensor or from other sources specified by him are also normally not allowed, nor are clauses restricting the direction of manufactured exports. Repetitive purchases of the same technology by different entrepreneurs or renewals of foreign collaboration on the expiry of their normal term are generally discouraged, the latter being with a view to compelling the Indian parties to take steps to absorb the foreign technology within the agreement period.

Development, promotion and utilisation of indigenous technology

The TPS also provides detailed guidelines on the development, promotion and utilisation of indigenous technology. The fullest support is to be given to the development of indigenous technology, to achieve technological self-reliance and reduce the dependence on foreign inputs, particularly in critical and vulnerable areas and in high value-added items in which the domestic base is strong. At the same time, strengthening and diversifying the domestic technology base are necessary to reduce imports and expand exports, keeping in view international competitiveness.

In order to foster invention and innovation, the TPS suggests the institution of a system of rewards and incentives to inventors (both individuals and enterprises), along the lines of the existing 'Independence Day' and 'Republic Day' Awards to notable inventors through the National Research Development Corporation of India. National awards from the Ministry of Industry are also recommended for major breakthroughs in import substitution.

The TPS draws attention to the need for upgrading and enhancing India's traditional skills and capabilities by using the knowledge and techniques of modern S&T. It envisages special support to technologies which result in low-cost production, less use of scarce items and greater use of local raw materials and resources, and marketability of products close to the point of production.

In view of the long period usually required for developing new technologies, the TPS calls for the early identification of relevant technologies in all priority areas, particularly where large investments or large-scale production are envisaged. After identification, it is necessary to fix time schedules, select institutions to implement the project, and ensure the provision of timely and adequate finances to complete it.

The Planning Commission Steering Group on Science and Technology, set up in connection with the formulation of India's Seventh Five Year Plan (1985-90), has accordingly suggested[9] the institution of a system of selective 'technology missions' to be activated in the industrial and other sectors during the Seventh and subsequent Plans. It has in addition emphasised the need to ensure proper linkages not only between different organisations and institutions engaged in research, production and related activities, but also between policies for indigenous technology development and those for technology import, so as to ensure that the utilisation of the results of 'technology missions' is not pre-empted by the import of foreign technology, leading to wastage of scarce resources on R&D.

In order to increase demand, the TPS has proposed the provision of incentives to users of indigenous technology and for the resulting processes and products. Policies already exist for granting preferential licences to products made substantially with indigenous technologies developed in recognised industrial R&D establishments and for delicensing the manufacture of products from technologies developed in national laboratories.

The TPS has emphasised the role of design engineering consultancy organisations in bridging the gap between laboratory-scale R&D and commercial production, and in promoting the utilisation of indigenous materials and equipment. It has suggested that the capability for total systems engineering, process development and project management should be developed, with foreign collaboration if necessary. It has also stressed the need for strengthening and upgrading design engineering capabilities and promoting Indian engineering consultancy, both in the public and the private sectors, on a sound professional basis.

The TPS considers in-house R&D units in industry to be an essential link between activities in national laboratories and production in industry. Accordingly, it has been suggested that appropriate incentives should be given to set up R&D units in industry, including those on a cooperative basis. Enterprises will be encouraged to set up units of a size which permits the accomplishment of major technological tasks.

Technology diffusion and transfer

The TPS refers to the need for making special efforts to ensure the diffusion of existing technology to all who can employ it well. Appropriate measures may include horizontal transfer, technological support for ancillaries of large units, technology inputs to small units, and upgrading traditional skills and capabilities.

The TPS recognises the need to maintain international competitiveness and standards in products, services and technologies that have export potential. Thus, conditions for marketing indigenous technology and resultant products may have to be improved. In order to promote technology exports, income tax exemption is allowed on half of any income received by an Indian company or from a foreign company or government for an invention, model, design, formula, process or some other form of industrial, commercial or scientific know-how or technical service.

The vertical transfer of know-how from R&D or academic institutions to industries in India is promoted primarily through the National Research Development Corporation (NRDC) by non-exclusive licensing of know-how on payment of a lump-sum fee coupled with recurring royalties at varying rates for specified periods. The NRDC also provides 'risk finance' for up to half the costs of 'development projects' to selected industries where a pilot plant, proving plant or prototype development facility is considered necessary to scale-up the laboratory-level know-how or to bridge the gap between laboratory-scale work and commercial activity. If the project is successful, the NRDC recovers its outlay as a soft loan; if it is not, then the NRDC's share of the cost is written off.

Structural change and adjustment

India's major experience of structural change and adjustment in response to technological transformation has arisen in connection with:

(i) the application of modern technology in the agricultural sector;

(ii) the promotion of health and family welfare programmes through adoption of new techniques; and

(iii) the introduction of computers in many organisations and institutions.

In agriculture, it was found that an absentee-landlord system, with a large number of tenant farmers, tended to discourage the investment in modern inputs (improved seeds, fertilisers, associated equipment, etc.) needed to raise productivity. The land-tenure system was therefore restructured throughout the country. Likewise, all state governments implemented laws in the 1950s and 1960s to consolidate landholdings belonging to individuals and prevent their fragmentation below an economic size through sale or inheritance. Consolidation helped farmers to achieve economies of scale (within the limits of 'land-ceilings', which were simultaneously imposed for socialist reasons) associated with the use of modern technology and to raise their productivity. At the same time, farmers' rural services and credit cooperatives were set up to organise the supply of agricultural inputs and credit at the village level. Lastly, community development activities such as agricultural extension and social education were promoted by the creation of non-official institutions at the level of the village, taluk, and district, which provided a mechanism of two-way communication between local communities and government.

In the promotion of preventive and diagnostic medicare and the introduction of new methods of family planning, 'Mahila Clubs', 'Youth Clubs' and other voluntary bodies have been extremely effective. Such groups distribute the more common medicines or simple family planning devices, etc., among the target population of remote areas, and have greatly facilitated implementation of Government health and family welfare programmes.

Finally, the introduction of computers (and many other radical or new technologies) in various industries, organisations and institutions has illustrated the great value of prior and meaningful consultations between management and workers' unions. Consultations have helped to reduce workers' apprehensions about the possibility of job losses or other negative effects of introducing new technologies and have thereby assisted in avoiding strikes, lock-outs, etc. It is, however, still too early to assess the outcome of the Government's new computer policy (see page 178 below), which was promulgated in November 1984.

At the national level, the Government has recently set up the National Council for Science and Technology Communication (NCSTC) to popularise S&T and inculcate a scientific ethos among the people[10]. The NCSTC has proposed that it should run training and orientation programmes for S&T communicators, monitor and evaluate S&T popularisation activities and tools, set up a National S&T Information Bureau, produce software for various forms of mass-media, and coordinate and orchestrate existing activities in this field. Such activities, in collaboration with those of various State Governments, voluntary agencies and other organisations, should greatly ease the task of transforming the technological basis of Indian society.

BANGLADESH

Objectives and priorities of science and technology policy

In the second Five Year Plan (FYP), instituted in July 1980, the Government of Bangladesh gave the highest priority to economic growth, employment generation and population control. It has done so primarily through the development of agriculture and the rural economy, which absorb large numbers of workers but have low output-capital ratios. In industry, emphasis has been placed on better utilisation of productive capacity and higher operational efficiency, as well as on more efficient utilisation of indigenous natural resources.

The country has given high priority to the application of S&T for achieving its development objectives and has set up various S&T policy, planning and executive organs. Principal among these are the National Council for Science and Technology (NCST), and the Science and Technology Division (S&TD); both are headed by the President, who is assisted by a Science Adviser.

The NCST, after undertaking an assessment of national needs, has prepared a National Plan for Science and Technology as an integral part of the FYP. Its main policy guidelines and priorities are as follows[11].

Main policy guidelines for S&T development

(i) to create a climate favourable to the development of S&T;

(ii) to develop an S&T capability to generate, select, adapt, absorb, use, maintain and operate technology;

(iii) to identify national needs where S&T are to be applied for socio-economic development, and to tailor S&T to these needs, particularly in the area of food, population control, education, health and housing. Some basic research is also essential to keep abreast of S&T development in the outside world;

(iv) to identify the most appropriate technologies for utilising major indigenous resources (people, minerals, soils, climate, etc.);

(v) to develop close interaction and cooperation between scientists/technologists, and planners, policy-makers and leading business executives;

(vi) to link S&T development to an effective manpower plan and to integrate it into the overall national development plan;

(vii) to develop close links between producers and users of technology; and

(viii) to generate a capacity for innovation among ordinary citizens and to give them the means and self-confidence to demonstrate their new ideas.

S&T priorities

(i) to strengthen education and training facilities for the creation of:

(a) middle-level technicians and skilled workers using technologies associated with 'basic needs' goods and services;

(b) professionals, technicians, managers and skilled workers to apply advanced technology; and

(c) high quality manpower to conduct and manage R&D and engineering works in scientific and technological institutions and supporting facilities;

(ii) to strengthen institutions for undertaking R&D on selected areas related to development objectives. Top priority would be given to engineering and the capacity for generating indigenous technology;

(iii) to promote effective design and engineering consultancy services;

(iv) to strengthen extension services, particularly in selected areas;

(v) to strengthen the information and documentation system and promote scientific and technological communication;

(vi) to promote the application of S&T for integrated rural development;

(vii) to intensify prospecting for and development of natural resources, prepare an inventory of such resources and to make efficient use of them;

(viii) to establish a National Centre for the Transfer and Development of Technology (NCTDT); and

(ix) to set up an institution for the domestic innovation and commercialisation of technology - the National Research Development Corporation (NRDC).

Because the Government of Bangladesh has given high priority to the development of food and agriculture, water resources, industry, energy, physical infrastructure and family planning, it should give corresponding priority to the acquisition or development of technology in these areas and make resource allocations accordingly.

Technology assessment and choice

Bangladesh does not yet seem to have effective criteria or institutional mechanisms to assess and select foreign technologies appropriate to its needs. Lack of domestic savings and foreign exchange have retarded its industrial growth, and the climate for its acquisition of technology through investment from other countries has not been very encouraging. Most projects based on imported technology have been turn-key in nature and the supply of capital goods has been financed largely through tied credits. In addition there have been three major and related internal constraints to the choice of technology. First, a lack of skilled and experienced individuals to make optimum decisions; second, inadequate national programmes or centres to provide the necessary information, training and extension services to identify, acquire, adapt and develop technology appropriate to local conditions; and third, insufficient local capital to fund such developments.

Role of foreign capital

In its revised industrial policy, the Government recognises that foreign investment can play an important role in Bangladesh. It considers that foreign investment should bring in not only technical know-how but also managerial skills and access to R&D and operational experience. Bangladesh now offers a number of financial and fiscal incentives to foreign private investors, including capital participation, repatriation and remittance facilities, compensation guarantees, and tax concessions. There are several other concessions applicable to both local and foreign investors, including rebate of import duties, services of utilities and credit facilities. Finally, the interests of foreign investors are protected by various laws.

Foreign technology absorption and adaptation

In view of the small amount of in-house industrial R&D in Bangladesh and the inadequacies of the S&T infrastructure, the prerequisites to foster and support a capability to absorb and adapt imported technologies are still largely to be developed.

Indigenous technology development, promotion and utilisation

Bangladesh is actively building up its infrastructure for the development, promotion and utilisation of appropriate indigenous technologies, as part of its strategy of self-reliant development.

Research institutions and universities are being built up for this purpose and their links with industries, government and other users are being strengthened. The proposed NCTDT should act as a focal point, providing information, training, consultancy and extension services, and strengthening capacities to select and negotiate technology imports, to unpackage technologies selected, and to decide which components should be produced domestically and which should be imported.

Technology policy development

Bangladesh is evolving a technology policy which envisages specific measures to narrow the technological gaps between the modern formal sector, and the traditional informal urban and rural sectors. In particular, the new R&D institutions are intended both to adapt imported technologies to make them suitable for local needs and to develop new technologies in keeping with the factor endowments of the country.

'Appropriate technology' is conceived by Bangladesh as a dynamic concept. Both labour-intensive and capital-intensive technologies are considered appropriate, but in different circumstances. A reasonable balance between the two is needed to maximise economic growth, employment and the satisfaction of basic needs, with capital as a major constraint. The Government recognises that technology choice must take account of working conditions and the environment. In addition it acknowledges that factor price distortions can lead to the selection of inappropriate technologies. Thus, to make an optimal choice of technology, there may have to be adjustments in policies affecting wages and prices, foreign exchange rates, taxes, interest rates, licensing, and resource allocation.

The Government envisages that for each project, the choice of technology will be specified and justified in terms of the major objectives of the FYP. The planners will be required to ensure compatibility between the country's technology mix and its socio-economic objectives. The Bangladesh technology policy will guide not only planners and those who choose technology, but also those who are concerned with the legal and financial aspects of the transfer of technology, who adapt or develop technology, and who are responsible for its eventual application.

The policy will also cover measures for training specialists in technology choice, transfer and development, in which respect educational programmes may need to be re-oriented to ensure that more students acquire relevant skills. It will in addition encourage and make provision for R&D to diminish the country's dependence on imported technologies. At the same time, technology users will be assisted with identifying, procuring and applying the most suitable technologies.

Structural change and adjustment

The Government believes that the technological transformation of Bangladesh society will depend on the nation-wide popularisation of S&T. The NCST has launched several programmes to attain this goal, including:

(i) supporting non-governmental S&T organisations, such as the Bangladesh Science Academy, the Bangladesh Association for the Advancement of Science, and the Bangladesh Institute of Engineers;

(ii) establishing a National Science and Technology Museum;

(iii) organising S&T clubs in educational institutions;

(iv) holding S&T exhibitions;

(v) instituting a 'National Science Week'; and

(vi) arranging lecture tours by scientists and technologists.

The Government also recognises that the technological transformation and successful development of rural areas hinges on the creation of appropriate and effective rural institutions, which must be organised to ensure popular participation in development activities, and the efficient delivery of supplies and services in rural areas. With that in mind, a National

Centre for Rural Technology has been established in the Bangladesh University of Engineering and Technology. In addition, rural technology extension services and training facilities are being built up for the promotion and management of rural industries (both on a cooperative and private basis). A number of village technology centres are also being set up to help maintain and repair new tools, machinery and equipment, as well as assisting with training, extension and other services.

SINGAPORE

Objectives and criteria of technology policy

The Government of Singapore believes that the foundation of a modern society must be based on the application of S&T to economic and social activities. To promote technological change, and thus economic growth, it pursues various policies of an essentially catalytic nature. These include the provision of infrastructure, scientific and technical manpower, R&D, supporting institutions, and investment incentives.

There have been three phases in the development of technology policy in Singapore. The first phase (1960-69) laid the foundation for industrial growth by the drastic restructuring of the country's political, economic and social systems. In response to the problem of unemployment exacerbated by a rapidly expanding population, the Government launched an industrialisation programme. This sought to create a more just and equal society, to increase job opportunities, to diversify the economic base from trading and mercantile activities to include manufacturing and service activities, and to provide workers with better training and education. Initially, the Government sought to tackle unemployment through the development of labour-intensive and import-substitution industries. Following Singapore's separation from the Federation of Malaysia in 1965, and the reduction of its domestic market, the limitations of this policy became obvious and the Government began to encourage a shift from import-substitution to export-promotion activities. During the second phase (1970-79), Singapore policies laid emphasis on high-technology, skill-intensive and high value-added industries, producing goods for the world market. As manpower shortages emerged, the emphasis shifted to more capital-intensive industries. Substantial incentives were offered to foreign investors in technology-intensive and high value-added industries, while existing industries were encouraged to upgrade their production technology. The Government also participated directly in the new industries, particularly where there was little capital investment from other sources. Lastly, entrepreneurs were encouraged to raise productivity to increase the competitiveness of Singapore's goods and services in world markets. In the third phase, which began in 1980, the Government has continued to pursue most of the policies and programmes adopted during the second phase. But in addition it has begun to develop the country's design capability in various engineering fields, and so reduce dependence on imported designs and increase the technical sophistication of local industries. Other long-term objectives include the use of S&T to solve a host of socio-economic problems. For instance, the Government is interested in the development of non-conventional energy sources and in the use of coal and nuclear energy to supplement oil; also with water desalination and environmental control, particularly the problem of waste disposal.

Role of foreign capital

A large number of foreign firms have set up operations in Singapore attracted by numerous investment incentives, the favourable infrastructure and availability of skilled personnel, as well as by the Government's belief in free enterprise, whether foreign or domestic. In 1977, foreign firms and foreign-controlled joint ventures together accounted for 23 per cent of the establishments in Singapore, 55 per cent of the employment, 65 per cent of the value-added in manufacturing and 85 per cent of the direct exports[12]. These foreign interests have played an important role in the modernisation of Singapore's economy.

Technology imports

In Singapore there are no administrative or legislative controls over technology acquired under licensing agreements. Instead the choice is left to the discretion of entrepreneurs. Technology and skills are also transferred to Singapore by joint ventures and foreign companies' subsidiaries.

As well as the incentives already mentioned, the Government has set up a special fund to meet the financial needs of foreign and local companies establishing technology-intensive manufacturing operations in Singapore. It may also invest up to half of the equity in new ventures, with the provision that this investment may be sold after the venture is operating successfully.

Technology assessment and choice

The Government has not established any specific mechanisms to assess and choose technologies. However, since the late 1960s it has encouraged high-technology and high value-added industries. Between 1965 and 1976, the proportion of value-added in Singapore's manufacturing industry accounted for by high value-added activities (e.g. electronic products, precision equipment) rose from 42 per cent to 72 per cent, whereas that contributed by low value-added activities (e.g. food, garments, leather products) fell correspondingly[13].

Indigenous technology development, promotion and utilisation

To stimulate indigenous R&D the Government has established various institutions and professional organisations, which are discussed below (page 181). R&D by the foreign-owned or controlled corporate sector in Singapore is largely concerned with product or process adaptation or application rather than with innovation as such. Many local firms, on the other hand, do perform R&D into new product or process design and development.

The Government exercises little control over industrial R&D. However, the Economic Development Board provides financial assistance under its 'Product Development Scheme' to industries undertaking R&D locally, with priority for products meeting criteria such as technological sophistication, export competitiveness and financial viability.

Structural change and adjustment

In order to promote the country's technological transformation, the Government has followed both promotional and interventionist policies. Numerous incentives have attracted foreign firms, including TNCs, which have brought with them the capital and advanced technological resources essential for Singapore's economic and social development. The realisation of local technological capabilities has also been encouraged by Government through institutional and financial support. However, "Most important of all in stimulating private foreign and local investment in manufacturing were the continuing political stability under the People's Action Party regime, its success in eliminating labour unrest and reducing strikes to minor proportions, and its generally even-handed regulation of trade-union and management relationships to prevent production costs and export prices from rising too fast compared to those of Singapore's competitors"[14].

During the late 1960s, enactment of the Employment Act (1968) and the Industrial Relations (Amendment) Act (1968) meant that after a long struggle, the Government appeared to have achieved a greater degree of control over the labour force and labour costs. The absence of labour militancy in Singapore remains an important factor in attracting foreign investment, and in promoting technological growth and social transformation.

TANZANIA

Technology policy evolution

The evolution of technology policy in Tanzania, like other countries, has been intimately related to its socio-economic goals and priorities as spelt out in its Five Year Plans (FYP) and in the Arusha Declaration. The major goals of its first FYP (1964-69) were:

(i) rapid growth of modern industry, *inter alia*, to raise productivity;

(ii) massive expansion of the education system;

(iii) increase in national savings and investment;

(iv) enhanced economic role for Government;

(v) modernisation of the agricultural sector; and

(vi) expansion of intra-African trade and economic cooperation.

In 1967 the Government issued the Arusha Declaration. This had five main themes:

(i) public control over large parts of the economy, viz. financial institutions, large-scale industry and commerce, and large-scale estate agriculture;

(ii) development through self-reliance, i.e. the decentralised domestic mobilization and use of local resources;

(iii) priority for the rural sector;

(iv) creation of a socialist society, primarily through cooperative production under the 'Ujamaa Programme' of collective ownership and community production in agriculture, and through nationalisation of key industries in the modern sector; and

(v) the creation of social equality, particularly by narrowing the gap in income levels, particularly between the rural and urban sectors.

Following the re-orientation of policies after implementation of the 'Arusha Declaration' and the FYPs the country developed a capacity to produce mass consumer goods, including food beverages, footwear and cloth as well as some intermediate goods like fertilisers, cement and rubber products. For a time prospects appeared good, but later internal economic difficulties and external shocks, such as the two oil price rises, led to setbacks which were exacerbated by the absence of a fully effective policy for technology. This lacuna has been reflected in part by the disappointing performance of both the agricultural and the industrial sectors and by the general lack of a technically skilled cadre.

Technological dependence

Tanzania continues to be largely dependent on foreign technology, much of it aid-financed. Imported technology is acquired through agreements, embodied in intermediate and capital goods, and through the use of expatriate personnel. Foreign direct investment is not a major channel for technology acquisition; foreign equity is permitted in industrial projects, but private foreign investment has been limited. The Government requires majority local ownership in joint ventures; but other conditions are flexible, negotiated project by project and varying from one sector to another, depending on national priorities.

When an enterprise wishes to import technology, it so decides; all that is required from Government is approval to acquire and use the foreign exchange. For new projects, there are elaborate procedures; but they relate not so much to the technology as such as to the costs and benefits of the project as a whole,and to its importance relative to national priorities. Such procedures may entail convening an inter-ministerial committee and approval by the Economic Committee of the Cabinet. Once approved, the task of deciding the nature and source of the technology required is normally left to the discretion of the ministry or parastatal. The inter-ministerial committees are concerned with the financial rather than the technological aspects of proposed agreements.

Normally in technology import negotiations, the Government involves representatives of institutions directly or indirectly concerned with financial and legal implications of a particular transaction. The National Development Corporation, a holding company which was set up in 1965 as the Government's main instrument of industrial development, has worked out a model management/technical agreement to serve as a guide to its many subsidiaries in the manufacturing sector.

Indigenous technology development and utilisation

The first important step towards developing indigenous technology in Tanzania was the establishment of the National Scientific Research Council (NSRC) in 1968. The NSRC's functions include:

(i) coordinating scientific research;

(ii) advising the Government on priorities for the allocation of research funds, scientific education, training and recruitment of research personnel, and the initiation, formulation and implementation of research policies and programmes;

(iii) promoting the documentation and dissemination of information; and

(iv) undertaking research in a variety of fields.

The NSRC operates through various working committees covering areas like food and nutrition, agriculture, building and construction, energy, medicine, scientific education and manpower, natural resources and natural sciences, and social sciences. It also has close links with the University of Dar-es-Salaam, which undertakes fundamental research in geology and other scientific fields. The NSRC has sponsored many basic research projects, and has set up the Tanzanian Research Information Service (TANRIS), whose main object is to promote the collection and dissemination of research results and information.

Over the last decade or so, a number of other organisations concerned with industrial promotion, advisory services and training have come into existence, mostly sponsored by the Ministry of Industry. Many of them have shown an increasing awareness of the importance of adapting and applying technology to local conditions. Among these organisations are: the Small Industries Development Organisation (SIDO) established in 1973; the Tanzania Industrial Studies and Consulting Organisation (TISCO)established in 1977; the Tanzania Manufacturing and Design Organisation (TEMDO); and the Tanzania Agricultural Machinery Testing Unit (TAMTU). In 1979 a new act established the Tanzania Industrial Research and Development Organisation (TIRDO). This is setting up a multi-branch Industrial Research and Services Institute (IRSI), with laboratories and pilot production facilities as well as testing and advisory services operating on a fee payment basis. The major divisions to be established in IRSI during the course of the country's 20 year Industrial Development Plan include: fibres; chemicals; engineering; food; and documentation.

The aim is to create a national system for domestic adaptation and development of technology. As yet, however, there does not seem to be any clear-cut technology policy with regard either to import or to the development and utilisation of domestic technology.

Structural change and adjustment

The most significant social step to facilitate and promote technological change has concerned education and manpower development. At the time of independence, the Tanzanian heritage of skilled manpower was quite meagre, and from the outset, the Government regarded educational and manpower development as a major instrument in achieving its social and economic goals. A policy statement by the Ministry of National Education in 1966 laid down that all employers must have a Tanzanian in training for every expatriate employee. Inadequate numbers of qualified Tanzanian candidates made this difficult to implement, however, and in the 1970s dependence on expatriates increased despite major efforts in education and manpower development. There continues to be an acute shortage of qualified persons in such fields as medicine, science, engineering and administration. The number of qualified persons continues to be insufficient to effect the structural changes in society needed to facilitate and promote technological change on an adequate scale for development.

Section 3

Institutional Framework for Implementation

INDIA

Indigenous technology development

Prior to independence in 1947, a number of notable S&T institutions existed, including the India Meteorological Department, Indian Research Fund Association (now Indian Council of Medical Research), Imperial Council of Agricultural Research (now Indian Council of Agricultural Research), and Council of Scientific and Industrial Research. In addition there were 20 universities. Since independence, an extensive institutional network has been set up. It includes the Atomic Energy Commission; University Grants Commission; Defence Research and Development Organisation; Space Commission; Electronics Commission; Research, Design and Standards Organisation of the Indian Railways; and the Telecommunications Research Centre. Many scientific departments have been established, including the Departments of Atomic Energy, Electronics, Space, Science and Technology, Agricultural Research and Education, Ocean Development, Environment, Non-conventional Energy Sources, and Scientific and Industrial Research. In addition there are nearly one thousand in-house R&D establishments in public/private sector industries and a large number of private scientific research foundations. A majority of these are engaged in applied R&D on industrial activities. The S&T departments of universities, institutes and colleges of higher technical education undertake R&D on basic and applied sciences and engineering. There are also numerous technical service/support/survey institutions, such as the Indian Standards Institution, National Test House, Botanical Survey of India, Zoological Survey of India, Small Industries Service Institutes, and Indian National Scientific Documentation Centre.

Many polytechnics and industrial training institutes located at district and sub-district levels train manpower skills for supervisory and operator jobs. Finally, many State Governments maintain research institutions and have set up State Councils of Science and Technology. All these activities form an integral part of the national S&T endeavour, overseen by the Planning Commission which considers S&T plans as an integral part of the country's socio-economic plan.

Various bodies have been set up to provide the highest levels of Government with scientific advice. The current body - the Science Advisory Committee to the Cabinet (SACC) - was established in 1981. It is serviced by the Department of Science and Technology, and has the following terms of reference:

(i) to advise on the formulation and implementation of Government S&T policy;

(ii) to identify and recommend measures to enhance the country's technological self-reliance;

(iii) to consider policy issues relating to the development and application of S&T which are referred to it by the Prime Minister or the Cabinet Committee on S&T;

(iv) to consider organisational aspects of S&T, including measures to provide adequate linkages between the scientific community, educational institutions, R&D establishments, industry and government; and

(v) to consider filling critical gaps in national competence, promoting technical cooperation among developing countries, and other issues concerning science in international relations.

In 1983, on the basis of SACC's recommendations, the Government set up the Technology Policy Implementation Committee, to facilitate and oversee implementation of its Technology Policy Statement made in January of that year. In January 1985, it established a National Microelectronics Council, to formulate, periodically update and review an integrated national plan for microelectronics (covering technology R&D, production, application, etc.), and to take decisions on all proposals for foreign collaboration and assistance in this area.

Technology import

As already mentioned (page 161), relatively high levels of foreign equity capital are permitted (under the Foreign Exchange Regulation Act (FERA) of 1974) in projects which have highly sophisticated technology (74 per cent) or are wholly export-oriented (100 per cent).

An inter-departmental committee under the Ministry of Finance is responsible for clearing cases under FERA. All technology imports under foreign technical or financial collaboration agreements are normally cleared by the Foreign Investment Board (FIB) set up in 1969 under the Ministry of Finance, though where imports of capital goods and industrial licensing are also involved, the Project Approval Board (PAB) set up in 1973 under the Ministry of Industry can grant a consolidated clearance. Both FIB and PAB examine such cases in consultation with the Departments of Industrial Development, Economic Affairs and Scientific and Industrial Research, the Directorate General of Technical Development, the relevant Ministry and other concerned organisations. Where necessary, the PAB also obtains advice from the Technical Evaluation Committee (TEC) set up in 1976 under the Chairmanship of the Director General of Technical Development, which examines the availability of indigenous technology and the suitability of the proposed technology import. In order to streamline and expedite the process for approval of foreign collaboration, the Government has allowed Ministries to approve such collaboration where there is no foreign equity participation, no extension of collaboration, and where the lump-sum and royalty payments are jointly less than Rs.5 million (gross) and the lump-sum is paid in standard instalments.

Technology imports may be assisted by the Technical Development Fund (TDF). This was set up in 1976 to promote technological improvements in existing industrial units by meams of imports of technical know-how, drawings, designs and 'balancing' equipment, and foreign consultancies. No more than Rs.10 million in foreign exchange annually can be approved under the TDF for any unit.

Using their own resources, industrial units are permitted to import drawings and designs to a value of Rs.2.5 million per year, subject to Government approval, though for export-oriented units, such imports are permitted to a value of Rs.2 million without prior approval. Higher amounts are considered in certain cases. There are further concessions for technology imports which are intended to cut energy and other material costs.

Technology embodied in capital goods may be imported, subject only to clearance by the interdepartmental Capital Goods Committee except where there is a formal technical or financial collaboration agreement with a foreign party. Under the 1985-88 import policy many capital goods may be imported without formal approval.

In March 1985, the Government announced a new set of policies for electronics. It includes the liberalisation of industrial licensing and technology imports in the electronics sector, and the permission of foreign equity participation of more than 40 per cent, with special emphasis on manufacturing electronic components and materials, and on other high technologies where India's R&D has been inadequate. Subsequently the Government decided to further liberalise imports of VCR/VCP technology, allowing it to be purchased by individual enterprises instead of centrally.

A new computer policy was announced in November 1984. This covers the manufacture, import and export of computers and computer-based systems and seeks to promote the application of computers for development. It also envisages the setting up of a Software Development Promotion Agency to boost the growth of labour-intensive software equipment for both export and local requirements, including import substitution.

Technology transfer and diffusion

India's national paper for the 1979 UNCSTD[15] included the following measures to promote the transfer and diffusion of new technologies:

(i) strengthening extension service capabilities;

(ii) building up appropriate information systems;

(iii) developing complete hardware/software packages;

(iv) establishing prototype and pilot plant facilities;

(v) fostering engineering design and consultancy service capabilities;

(vi) establishing relevant training programmes for entrepreneurs and managers;

(vii) providing risk capital and fiscal incentives for indigenous technology; and

(viii) creating appropriate institutions for implementing the above measures.

There are already numerous institutions in India capable of fulfilling these goals. For example, the NRDC has had success in carrying the benefits of S&T to rural people and in developing technology appropriate to other developing countries. It has also assisted others to carry out R&D and to file patents and pursue their acceptance, sealing and renewal. In addition it publishes a variety of literature on available technologies, the promotion of invention, and services related to technology development, transfer and diffusion in India. Another important organisation in technology diffusion is the National Productivity Council (NPC), established in 1958 as an autonomous entity under the Ministry of Industry. This seeks to stimulate productivity consciousness, help maximise the use of resources, and thus raise living standards in India. It disseminates information about the concepts and techniques of productivity and management through various media, and organises management seminars and training programmes. It also offers consultancy services, for which there has been growing demand, to help industry, government and service organisations to improve their operational efficiency.

A large number of other government, quasi-government and voluntary organisations have been doing notable work over past decades in the development, transfer and diffusion of appropriate technologies, particularly to rural areas. They include the Khadi and Village Industries Commission (KVIC), the Small Industries Extension and Training Institute (SIET) (Hyderabad), the Council for the Advancement of Rural Technology (CART) (New Delhi), research laboratories under the CSIR/ICAR/ICMR, the Council for Research in Indian System of Medicines (New Delhi), and the ASTRA programme of the Indian Institute of Science (Bangalore).

The biggest success in technology transfer in India has been in agriculture. The agricultural extension system has been promoted jointly by the Central and State Governments, though it operates primarily through the State Agricultural Departments. The sources of know-how of the agricultural extension agencies are the various national and regional research institutes under the Indian Council of Agricultural Research, state universities of agricultural sciences and other regional or local research stations. The research institutes usually carry out field trials of new seed varieties, other agricultural inputs, and improved techniques before attempting to transfer them to farmers by field demonstrations. The new Training and Visit (T&V) System, with a village worker (assisted by supervisory agriculture officers) giving farmers advice on modern techniques and practices, has also been found effective.

In health and family welfare, the extension and delivery system is also primarily managed by State Governments, with some support from Central Government. However, the operation of family welfare bureaux, urban and rural family welfare centres, supply of contraceptives, and education are funded centrally, as are the programmes against blindness, tuberculosis and leprosy. There are also a large number of voluntary organisations in India which promote knowledge about preventive health care, small family norms, etc., as well as rendering actual medicare or family welfare services.

Finally, the State Councils of Science and Technology, which have been set up by nearly all State Governments, have also initiated potentially important programmes in agriculture, health, energy, environmental sanitation and hygiene, and urban/rural development. This has involved both the application of existing technologies and the development of new ones in areas of special relevance.

BANGLADESH

Indigenous technology development

The institutional system for planning and developing indigenous S&T in Bangladesh has three parts. Decisions are made by members of the Presidential Cabinet, either individually or through a Cabinet Committee or collectively at a Cabinet meeting. Policy formulation and planning is carried out by the National Council for Science and Technology and the Science and Technology Division, both headed by the President, assisted by a science adviser. Promotion and execution of the S&T policies, plans and programmes at sectoral levels are entrusted to (i) Government Ministries and Departments; (ii) quasi-government organisations, including universities, research councils, development boards and industrial corporations, and (iii) non-governmental bodies and international organisations. These agencies control and work through a network of R&D institutions and supporting facilities, which are mostly financed by Government.

With regard to the development of trained and skilled manpower for various types of S&T activities and services, the country has several universities, post-graduate institutes, colleges and other training institutions. Informal training facilities are quite extensive and are reported to have created a commendable force of technicians.

For the provision of supporting services, several institutions have been set up, such as the Bangladesh Standards Institution and the National Scientific and Technical Documentation Centre, besides a number of natural resources survey and exploitation institutions.

Technology import

The Department of Industries is entrusted with implementing the Government's investment and technology policies. All foreign private investment requires approval by the Investment Board, which is headed by the Minister of Industry (or his adviser), with the Department of Industries acting as the Board's secretariat. The Department has issued guidelines for foreign investment and technology imports. However, there seem to be no comprehensive mechanisms for the regulation and promotion of technology transfer. Particularly important in this respect is the need to help entrepreneurs to get information on, and access to, alternative sources of technology, to unpackage technologies to be imported, and to negotiate more favourable terms for technology acquisition.

Technology transfer and diffusion

The functions of the proposed National Centre for the Transfer and Development of Technology have already been described (page 18). It would also coordinate the activities of other organisations concerned with technology transfer and attempt to maximise the use of indigenous capacities. In addition, it would collect information on locally available equipment and machinery, technology research and design, engineering capabilities, and industrial infrastructural services. Through holding seminars, industrial clinics, and exhibitions, etc., it would try to popularise technologies already being used successfully and help other institutions to develop the capacity to adapt existing technologies to suit local needs and conditions. Finally, it would liaise with similar centres abroad. Also relevant are the National Centre for Rural Technologies and the non-governmental S&T organs described earlier (page170). Among the latter, the National Science and Technology Museum displays devices and models to increase public understanding of scientific principles and their practical applications. It also organises science clubs in educational institutions and arrange science exhibitions. Finally, the annual celebration of a National Science Week is being promoted throughout Bangladesh.

SINGAPORE

Indigenous technology development

In 1968, the Government set up the Ministry of Science and Technology with responsibility for devising policy guidelines and programmes for the application of S&T, training of scientific and technical manpower, encouragement of R&D and promotion of awareness of S&T as a tool for economic and social development. In 1973, the Applied Research Corporation was set up as a non-profit-making organisation to work on specific problems and offer consultancy services. A Science Council was established in 1967 to advise the Government and promote S&T.

Technology support services

The Singapore Institute of Standards and Industrial Research provides technical and engineering services to industry. Among its major functions are the provision of testing facilities and determination of standards and specifications for local products. The Department of Scientific Services provides testing and analytical services in a variety of fields; they include chemical and micro-biological quality control and radiation protection, as well as assistance with manufacturing problems.

Manpower training and development

In recognition of the importance of manpower training and development to the successful transfer and development of technology, the Government has given special attention to the supply of technical and specialised personnel. The Manpower Division of the Economic Development Board (EDB) coordinates the development of labour resources, administers the Government industrial training subsidies, supervises training programmes, and facilitates the entry of professional and technical personnel into Singapore.

Under the Joint Company Government Training Scheme, the EDB in conjunction with some established international companies has set up centres to train young apprentices in precision engineering and craft skills. It also coordinates the Overseas Training Scheme and the Industrial Development Scholarship Scheme. The former provides new companies with an opportunity to prepare key personnel for their operations in Singapore, while the latter offers financial assistance to companies providing not less than six months of advanced training in specialist engineering and supervisory skills not available in Singapore. These schemes provide valuable experience and know-how on modern manufacturing practices to technical and managerial personnel.

The National Productivity Board, which aims to raise productivity in all sectors of the economy, organises training courses to upgrade the skills and knowledge of supervisors and managers in management, technology and productivity-related areas.

The University of Singapore provides degree courses in various branches of engineering. Singapore polytechnic and other technical institutions train technicians to meet the growing demands for supervisory staff. In schools also, increasing emphasis is being laid on the learning of science and mathematics to serve as a base for future technical education and training, an emphasis which is also reflected in the vocational institutes which offer courses in a variety of trades. The Industrial Training Board coordinates the training of workers.

TANZANIA

In Tanzania several institutions have been established specifically to facilitate and promote the selection, acquisition, adaptation, development and utilisation of technology (see page 24). Others have been set up primarily for different purposes but nevertheless undertake functions which affect technology. These institutions include the Tanzanian Investment Promotion Committee, Industrial Studies and Development Centre, Investment Bank, National Small Industries Association, and State Trading Corporation. The impact of these institutions has been rather fragmented, however, and in other ways less than satisfactory. In consequence, to ensure that transferred technology is appropriately harnessed and adapted to local conditions, an UNCTAD mission[16] has recommended that the Government should:

(i) lay the foundations for formulating and implementing an integrated national technology policy in the context of the country's overall development strategy;

(ii) designate for this purpose a focal point, such as the S&T Department of the Ministry of Planning, which would have a coordinating role and would be assisted by other institutions;

(iii) register, evaluate, select, acquire, unpackage (where possible) and monitor foreign technologies in an integrated fashion and on an institutional basis;

(iv) assist domestic enterprises find alternative potential suppliers of technology in accordance with the priorities of national development planning;

(v) give higher priority to, and make appropriate arrangements for, technical skill formation and the development of indigenous technological capacity, including R&D; and

(vi) initiate the first steps towards technology planning, starting in key sectors.

Section 4

Overall Assessment

INDIA

Indigenous technology development

India has a strong S&T base with an extensive range of research and training institutions and the third largest pool of S&T manpower in the world. The country's performance in S&T, however, has been mixed. On the one hand, it ranks among the world's leaders in such areas as the development of atomic energy and the use of space technology for communications, natural resource surveys and meteorological forecasts. Its development of agricultural S&T and the performance of its agricultural extension agencies have also been commendable, contributing to a surplus in foodgrains despite considerable population growth. On the other hand, India's performance in the provision of housing, sanitation and drinking water, and in the control of communicable diseases, has not been entirely satisfactory. Equally important, the exploitation of India's huge S&T potential for industrial development appears with few exceptions to have been inadequate and ineffectual. Major constraints include the shortages of trained manpower in engineering which have restricted the commercialisation of research results; the lack of 'venture capital' or of any scheme to insure against risks in transferring domestic technology to industry; and the inadequate linkages between policies for technology development and for technology import.

Technology import

In India, the main problem concerning the acquisition of foreign technology seems to be the multiplicity of channels introduced over the years to permit imports. The duplication is particularly marked for industrial technology, and some rationalisation should be possible.

While the existing guidelines for foreign collaboration lay down certain products where technology imports are not normally permitted, a complete list of priority areas where technology imports are liberalised is still to be compiled. Nor do existing policies take account of the impact of imports on the development and utilisation of indigenous technologies. There are no clear linkages in policy between the two, with the result that the commercialisation of indigenous technology, on which considerable R&D expenditure has already been incurred, is often pre-empted by imports. Better linkages are clearly needed.

Although the major repositories of indigenous industrial technologies in India are in theory involved in Government decisions on technology imports, in practice imports are rarely restricted in order to protect indigenous technology, as it is usually claimed that the latter has not been proven on a commercial scale. This problem is perpetuated by a lack of funds for pilot testing of indigenously developed technologies.

Nor is there any law or other mechanism to involve national R&D institutions with the process of technology imports at the enterprise level, a lacuna which is adversely affecting the absorption and adaptation of imported technologies.

Another weakness is that there are as yet no specific guidelines for assessing technologies in relation to their techno-economic efficiency, energy consumption, employment potential and environmental impact, etc. In their absence, the Technical Evaluation Committee (TEC) of the Ministry of Industry appears to use ad hoc criteria to evaluate technology imports. Its work is made more difficult by the lack of relevant data on comparable technologies. The proposed establishment of a National Register for Foreign Collaboration and a Technology Data Bank, together with the evolution of clear guidelines for technology assessment, should help to improve the situation.

With regard to imported technology absorption and adaptation, the DSIR has evolved a scheme for financial/ technical assistance to industry. It is, however, too soon to be able to assess the scheme's efficacy.

In sum, there appears to be considerable scope for refining India's current policies on technology import, to align them with its technology development policy, and to accelerate the inflow of 'appropriate' technologies in defined 'priority' areas.

Technology transfer and diffusion

The Indian strategy for the transfer and diffusion of technology into its economic and social system has been most successful in agriculture. Concerted efforts to diffuse 'rural' technologies, however, have only begun in recent years, and the use of non-conventional sources of energy and of 'intermediate' technologies, as well as the 'blending' of modern technologies with traditional ones, may need to be monitored closely in rural areas.

The responsibility for propagating new methods to prevent, diagnose and control various diseases lies primarily with the State Governments. The overall experience with the existing health-care delivery systems and family welfare programmes, particularly in rural areas and urban slums, has been mixed, with inadequate funding and rather ineffective implementation machinery being major problems. Finally, in the industrial sector, the performance of agencies involved in the development and transfer of domestic technology to small-scale and tiny industries has been fairly satisfactory, although (as discussed above) their efforts at commercialising major industrial technologies have been much less so. There are other mechanisms in India for technology diffusion, such as the National Council for Science and Technology Communication, but most are too new for their success to be judged.

BANGLADESH

The evolution of S&T policies and of the implementing infrastructure is still in its initial stages in Bangladesh. Proper mechanisms to regulate technology imports, and to facilitate choice, unpackaging, absorption and adaptation of such technologies are yet to be evolved. Meanwhile, existing institutions for the development of indigenous technology appear more academic than business-oriented. They also seem to lack the organisation, manpower, and financial and fiscal facilities, needed to develop S&T effectively and to apply it to the country's socio-economic development. However, recently initiated technology transfer and diffusion programmes hold out considerable promise of improvements in this respect.

SINGAPORE

It is difficult not to conclude that Singapore's socio-economic and technological development policies have been highly successful. Not only do their goals appear to have been well designed, in keeping with the requirements of a small territory lacking in natural resources, but their implementation has been relatively effective, and no doubt this contributed to the creditable economic performance of the country. Its economy is now focused on technology-intensive and high value-added industries, which in general are competitive internationally. If the resources vested in the various foreign companies operating in Singapore are excluded from the assessment, however, the country's indigenous technology base appears much less strong, especially in industry. All the same, it is indisputable that Singapore has transformed itself from an economy based essentially on services and trading, into one which is both diversified and prosperous, despite the recent slowdown in growth.

TANZANIA

It can be seen from the earlier discussion that technology policy in Tanzania is still at an early stage of evolution. But existing institutional mechanisms do not seem to have been very effective either for selecting and adapting imported technology or for developing indigenous technology. Various measures have been suggested (e.g. by the UNCTAD mission cited earlier) to enhance the effectiveness of its technology policy and related institutional machinery in order to realise the country's long-term goal of technological self-reliance.

Part II

TECHNOLOGY POLICIES AND ECONOMIC AND SOCIAL DEVELOPMENT : PLANNING FUTURE IMPROVEMENTS

Section 1

Introduction

This part of the report attempts to provide a conceptual policy framework at macro- and micro-levels to promote and facilitate technological change and suggests associated structural adjustments, both nationally and internationally. Before proceeding, however, it may be useful to make certain preliminary remarks about the concept of technological change and the impact of technology on society.

New technologies emerge through the process either of 'technology-push' (the supply of technology) or of 'market-pull' (demand). In analysing the mechanics of technological change and devising appropriate promotional policies, several parties and criteria need to be considered. These include the technology supplier, the recipient or client, and in the case of 'technology-push' categories of change, the technology change 'agent' (or 'extension agency') whose function is promotional. In societies or organisations with low levels of literacy and technological orientation, or traditions and cultures resistant to the introduction of new techniques, the change agent's task is extremely important. It may involve setting up demonstrations to convince potential clients of the benefits of new technology, and identifying and removing obstacles to change.

It is now well-understood that technology interacts with society in various ways. They include its impact on: the environment and ecology; income distribution; employment (quantity, pattern, duration, nature, occupational health and safety); public security; consumption patterns; cultural values; and training. All these aspects need to be taken into account in formulating any policy to manage technological change,to maximise its benefits and minimise its costs.

We can now discuss the nature of the policy issues involved in the management of technological change, and suggest specific policy measures for ensuring its successful management by countries at different stages of development.

Section 2

Policy Issues

The promotion of technological change raises many policy issues. They include the need to decide whether technological change should be promoted primarily through imports or more by developing and utilising indigenous technologies, resources and manpower; the nature of technologies/goods to be imported or developed and utilised indigenously; the criteria for assessing and selecting technologies; the R&D priorities for indigenous technologies; the associated requirements of technology development, support and manpower training; the fiscal and monetary policies for promoting technology imports, and indigenous technology development and utilisation; and the means to transfer and diffuse technologies within the country. We restrict our discussion to some of the more important of these issues.

As far as technology imports are concerned, various policy measures can be adopted by governments. They include the enactment of suitable patent laws to protect the industrial property rights of the foreign technology suppliers in the host countries; the conclusion of double taxation agreements; and the implementation of corporate taxation and other fiscal policies to attract the foreign suppliers of technology.

But the choice between imported and indigenous technologies is not exclusive. As the Government of India's Technology Policy Statement (January 1983) puts it, "technological self-reliance" does not imply "technological self-sufficiency". Even the most advanced countries engage in a two-way flow of technology. On the other hand, continued dependence on foreign technology and other inputs, especially in strategic sectors, can endanger a country's economic and even its political independence. By reducing the demand for indigenous technologies, it tends to sap indigenous initiative and perpetuate the 'vicious circle' of technological dependence or 'technological colonialism'. This, in turn, further weakens local production and S&T capabilities. Inadequate assessment mechanisms lead to the import of inappropriate technologies, while indiscriminate imports may not suit the cultural and social preferences of the majority of people in the importing country.

In this situation, countries in the initial stages of development need to begin by developing indigenous capabilities in basic needs' sectors such as food, energy and transport, and other strategic sectors like defence. Imports of know-how, equipment or materials even for these sectors should not be excluded automatically, but the indigenous availability of relevant capabilities or inputs, and the possibility of developing them,should be considered first. Once strategic sectors have been indigenised, countries should select other sectors where domestic technological capabilities are reasonably strong or could be built up quickly, with a view to increasing employment and promoting import substitution. As countries begin to fulfil the basic needs of their people, they should attempt to develop or acquire technologies that raise productivity and international competitiveness. This may require importing technologies, but in doing so, care is needed to avoid weakening domestic R&D capabilities or markets. This necessitates careful management of tariffs, subsidies, and other fiscal policies for promoting domestic R&D capabilities to produce indigenous technologies or products which are internationally competitive. Likewise, where technology imports are banned, special measures are needed to develop indigenous R&D capabilities.

Another important area is the process of technology diffusion. Although this differs from one country or sector to another, there are some essential requisites common to most cases:

(i) training personnel in the use of new technologies;

(ii) training extension educators or other 'change agents', who often have to intervene between the suppliers and recipients of know-how, particularly in agriculture and health but also, in many cases, in industry and services;

(iii) organising inputs (including machinery, equipment, raw materials, finance, infrastructure) required to operate new technologies;

(iv) adapting and absorbing technologies transplanted to new social/economic/geographical/agricultural/political environments;

(v) organising effective 'feed-back' systems from the ultimate beneficiaries and recipients of new technology, to extension agencies and suppliers;

(vi) developing a cadre of research staff competent to make use of such 'feed-back' and to improve existing products and technologies; and

(vii) enacting special measures to assist those adversely affected by technological change, in order to overcome their resistance to such change.

Adaptation of technology to new situations throws up a variety of problems. Adapting to a new social environment may be necessary to ensure that the end-products suit the preferences of the new group of consumers; adapting to changes in economic factors may involve, say, the use of less mechanised techniques where capital has become scarcer and labour more abundant; adaptation to a new geographical climate may require 'tropicalisation' of designs and/or equipment; promotion of new products in a different cultural environment may involve influencing people's consumption habits or mental attitudes; and adaptation to a new political environment may involve various changes in technology.

Absorption of technology in a country or organisation depends not only on the technological abilities of the recipient but also on its social and economic policies and legal framework. For instance, if a country bans the renewal of foreign collaboration agreements, industrial enterprises will need to take steps to absorb the foreign technology within the period of the agreements.

Resistance to the changes which would result from introducing new technologies is, perhaps, central to the successful management of technological change. The major causes of such resistance include: economic factors (e.g. the effect of new technology on the distribution of income and wealth); social factors (e.g. personal inconvenience and feelings of insecurity; violation of established norms; absence of prior consultation or debate; concern over changes in the structure of society; adverse impact on health and safety); and environmental factors.

Resistance to change is primarily a 'human' problem and not a 'technical', 'financial' or 'legal' one. If handled sympathetically, it may be reduced if not totally eliminated. For instance, it seems that change (whether technological or otherwise) is usually more acceptable: when all its implications are understood; when it does not seem to threaten security; when those affected have helped to create it rather than having it imposed upon them; when it is preceded by consultation or education; when it is implemented after any previous changes have been successfully assimilated; when those affected can see the gains; when it results from accepted policies or principles, rather than from diktats or fiats; and when its outcome is reasonably certain. Within organisations, change is usually more acceptable if the staff have been trained to plan for improvements rather than accustomed to static procedures. Lastly, change is more acceptable to people new to a job than to those well established.

Appropriate policies therefore include general extension education; better communication with the people affected, including their involvement in the decision-making and/or implementation processes; and adjusting the pace of technological change.

Section 3

Technology Policies

Here we consider policies relating to technology assessment and choice, the development and promotion of indigenous technology, and the transfer and diffusion of technology. Policies concerned with monetary and fiscal incentives, manpower requirements, environmental controls and legal instruments are discussed in subsequent sections.

Technology assessment and choice

Technology assessment (TA) is needed because project appraisal systems in most countries are usually confined to economic cost-benefit analyses, which focus on profitability, foreign exchange balance and other financial considerations. Social costs and benefits, such as the impact on employment, income distribution, working conditions, environment and so on, are generally ignored. It is because many new technologies have been observed to affect these areas adversely, that there is now growing support for TA - to take account of such impacts when making decisions about the choice of technology. While TA is designed to lead to a more appropriate choice of technologies in relation to socio-economic and other national goals, it is important to ensure that 'technology assessment' does not become 'technology arrestment' through undue concentration on the possible adverse effects of new technologies without consideration of possible solutions.

The United Nations Environment Programme (UNEP)[17] has suggested the following general criteria for TA: satisfaction of basic human needs; promotion of the concept of self-reliance through the use of domestic human and natural resources; and environmental soundness. Additional criteria could include: maximising employment and/or production per unit of investment; maximising energy efficiency or increasing the use of alternative, renewable energy sources; maximising use of indigenous raw materials, manpower and other resources; and simplicity of operation or maintenance of machinery or products. The choice of criteria, and the weights assigned to them, may vary from sector to sector as well as between countries. A distinction should also be drawn between TA conducted in the public and private sectors[18]. In the public sector, three elements are essential for successful TA: the assessment must be conducted in a flexible structure, by inter-disciplinary teams, with provision for public discussion of the results. In the private sector, a decentralised approach may be more appropriate, with individual industries conducting TA of the products and processes they have developed. As regards the institutionalisation of TA, the United States National Academy of Sciences has made the following recommendations[19]:

(i) the agency must be insulated from direct policy-making powers and responsibilities, lest it acquires a vested interest either in promoting particular technologies or in maintaining the status quo;

(ii) the agency must not be given the authority to screen or clear new technologies itself, so as not to give it a veto power over all other agencies or authorities of Government;

(iii) the agency should have the power to study new technologies and make recommendations to the appropriate authorities, being so located organisationally that its recommendations are influential, but it should not act either in support of or against any innovation; and

(iv) the agency must make a special effort to hear diverse viewpoints, particularly of citizens' groups and private associations, as well as business and government organisations.

In conclusion, there are strong arguments for all countries to undertake TA. This is especially so for newly industrialising and other developing countries, whose societies are experiencing rapid technological transformation. TA should be institutionalise with a view to improving the choice of technologies, investment policies, and research priorities. It should cover both imported and domestically developed technologies.

Development and promotion of indigenous technology

As discussed earlier, the aims and objectives of a country' technology policy should be derived from its socio-economic, security and other national goals. The policy itself should cover technology imports, development, diffusion and utilisation. It could be in the form of a Science and Technology Plan, specifying, inter alia, the priorities, programmes and projects for investments in S&T activities. Such plans are now being prepared in developing countries like India and in the centrally-planned economies as an integral part of the state's socio-economic plans. Implementing the S&T plans is carried out by research laboratories, academic institutions, in-house industrial R&D establishments and various technical service or support institutions - in some cases new institutions may have to be set up to complement existing ones.

We now turn to the issue of research priorities and of associated policy-linkages, and the types of S&T institutions needed.

Research priorities

It has been suggested[20] that in determining its research priorities a country should delineate the areas in which: indigenous technologies are to be the basis of productive activities; traditional technologies must be preserved and developed; and capabilities for choosing, modifying and absorbing the imported technologies must be built up. A country seeking self-reliance should start with critical and vulnerable sectors. For instance the Government of India's Technology Policy Statement envisages the fullest support in the development of indigenous technology to achieve technological self-reliance and reduce dependence on foreign inputs in such areas as defence, agriculture, and energy. The next areas of priority include those sectors which, potentially at least, would add substantial value to a country's natural resources or to its imported raw materials or other goods. These are very broad criteria and within each sector they would need to be further refined in consonance with overall socio-economic priorities.

The guidelines[21] adopted by the Government of India in the mid-1970s for its sponsored scientific research may serve as a model for other countries. These directed research to:

(i) create or develop any new source of energy capable of being commercially exploited and improve efficiency of any existing method of energy generation/distribution, and create or develop any new source of proteinous and/or other nutritious food for human consumption;

(ii) conserve energy, food or any other scarce material resource by devising new or improving existing methods of processing/manufacture;

(iii) devise better techniques for utilising or re-cycling wastes;

(iv) develop better techniques for controlling or reducing pollution;

(v) develop improved basic drugs/medicines for treating more commonly prevalent human/animal diseases;

(vi) develop improved techniques of family planning, likely to find wide acceptance;

(vii) develop improved techniques of construction (including new building materials) to reduce costs substitute common for scarce materials, especially in rural areas;

(viii) develop improved plant nutrients and plant protection chemicals to raise agricultural yields;

(ix) devise new production techniques which conserve foreign exchange; and

(x) achieve such other prescribed national social, economic and industrial objectives.

It would seem useful for other countries, especially developing ones, to formulate their own research priorities in this way, in keeping with their own national goals and bearing in mind the limited resources available for investment in R&D.

Policy linkages

Once priorities for indigenous technological development have been identified and decisions taken on investment in supporting relevant R&D, it is necessary to ensure their consistency with a country's

(i) regulatory policies, if any, governing the establishment of economic activities based on indigenous know-how;

(ii) long-term technology import policies, to ensure that future imports do not pre-empt the utilisation of indigenous technologies; and

(iii) policies relating to resource allocation for production, due priority being given to setting up production-units based on indigenous technology.

As the experience of India and, perhaps, of other countries shows, lack of coordination of such policies leads to unnecessary waste of resources invested in indigenous technological development.

Technology development institutions

As an instrument of policy, institution-building is relatively recent, and in many developing countries, S&T institutions have come into existence piece-meal, mainly as a result of sectoral initiatives. In a few countries, however, including India and Singapore, a cohesive network of S&T institutions has been established through government policies to promote specified goals. Such institutions include those devoted to R&D, technical services/support, natural resources surveys, technology transfer, and manpower development. Their establishment, and the linkages between them, should be related to a country's economic and social development goals. Institutions whose objectives are mutually contradictory or in conflict with major national goals or policies should obviously be avoided. Their links with industry and other users, academic/training institutions, and concerned Government departments also need to be promoted.

Technology development institutions can be broadly classified as follows:

(i) government/quasi-government R&D laboratories set up on a discipline-oriented basis;

(ii) cooperative research associations;

(iii) private research foundations and trusts which undertake independent contract research;

(iv) in-house R&D units in industry;

(v) institutes or colleges of engineering and technology or technical departments in universities, undertaking contract research or consultancy work; and

(vi) institutions upscaling laboratory know-how into commercial activity. In most cases, such activities are undertaken by industrial units themselves, with or without support from other R&D or technology transfer institutions.

It is difficult to commend any technology development institution as a model for all countries or situations. However, experience in the industrial countries, and many developing countries, seems to suggest that industrial R&D is best performed in close proximity to production lines or through industrial cooperative research associations. A competitive environment to promote technological innovation, governmental support, provision of needed finance, equipment and manpower are other preconditions of successful technological development. Government or quasi-government research laboratories and other institutions engaged in developing industrial technologies seem to be most effective, and of greatest social relevance, when they function on the basis of a 'customer-contractor' relationship.

Technical service and support institutions

Technical service and support institutions form a crucial link in the generation of domestic technology as well as in making the best choice and use of imported technology. While some of these institutions provide the required data base/ information and other facilities needed to plan and perform R&D activities, others help in commercialising the results of such activities. The functions performed by these institutions fall broadly into the following categories:

(i) collecting and disseminating technological information (undertaken by national registries, technology data banks, information and documentation centres, and specialised S&T libraries, etc.);

(ii) surveying and mapping natural resources;

(iii) standardisation, testing and quality control;

(iv) electronic data processing (undertaken by centralised computer facilities);

(v) selecting appropriate technologies, equipment and materials; designing and engineering production plants; preparing feasibility and project reports; undertaking management and training; and providing economic/financial consultancy services.

While the functions performed by these institutions are essential to technological development, the role of design-engineering-consultancy organisations in translating the results of lab-scale research into commercial activity may be one of the most crucial. Likewise, these institutions' rich experience of technology transfer is specially valuable in helping them to undertake their role in technology assessment and choice, both of domestic and imported technology.

<u>Technology transfer and diffusion</u>

By translating or carrying research results from laboratories and other R&D institutions to industrialists, farmers and others, technology transfer institutions (e.g. national research and development corporations and agricultural extension agencies) play an important role in the process of technological change. Also important are those institutions devoted primarily to the popularisation of science and technology, such as the National Council for Science and Technology Communication (NCSTC) in India, science and technology museums, and academies or associations of scientists and technologists.

A resolution on technology transfer adopted at UNCTAD IV recommended[22] that each developing country should ensure "the establishment of appropriate institutional machinery, including a national centre for the development and transfer of technology, with urgent attention being paid to defining the role and functions of such a centre, including the principal linkages which need to be established with other national bodies or institutions". The UNCTAD Handbook on the Acquisition of Technology by Developing Countries[23] suggests that national centres for the development and transfer of technology should: assist, within the framework of national social, economic and political constraints, in the identification of technological needs for a variety of economic activities; assist in the acquisition and analysis of information required on alternative sources of technology from all available sources, domestic and foreign, and in its delivery to users; assist in the evaluation and selection of technologies appropriate for different jobs, with an emphasis on decision-making; assist in unpackaging imported technology, including assessing its suitability, direct and indirect costs, and the conditions attached; assist in negotiating the best terms and conditions for imported technology, including arrangements for registering, evaluating and approving agreements for its transfer; promote and assist the absorption and adaptation of foreign technology and generation of indigenous technology, linked specifically to design/engineering, research and development; promote the diffusion of technology already assimilated, whether indigenous or foreign; and coordinate policies and evaluate their internal consistency in relation to the transfer and development of technology.

These national centres should have a double impact: at the macro-level on the formulation of technology policies and a technology plan, and at the micro-level on the productive system and enterprises themselves, both public and private. According to the UNCTAD Secretariat,[24] the centres need to be linked with other institutions and agencies such as: the planning organisation responsible for formulating the development strategy and drawing up the development plan or programme; the authorities responsible for approving foreign investment and for devising and administering investment laws, regulations and fiscal or other incentives; the organs responsible for project preparation and/or appraisal; the education and training system, for both planners and skilled manpower; the organs responsible for industrial property, standardisation and quality control; the R&D institutions (which are too frequently isolated from both imported technology and the productive system). It is, however, recognised that such structures may be difficult to establish and implement effectively in free-market economies where governments exercise little control over technology acquisition by individual enterprises and the development and transfer of technology within the country.

Within industries, technology transfer and diffusion can be promoted in a variety of ways which encourage backward and forward linkages with other industrial units. They are greatly facilitated by encouraging the mobility of S&T personnel, not only from one place of work to another (e.g. by encouraging scientists to hold lecture tours), but also by institutionalising staff exchanges between sectors like education, industry and research. Organisations like National Productivity Councils or Boards, as in India and Singapore, are also crucial, by making industries, organisations and individuals more conscious of the role of improved technologies and management techniques and providing the necessary training and consultancy services.

While there are many institutional mechanisms for the transfer and diffusion of technology in the industrial sector, that into rural areas requires different types of institution. In agriculture, the example of India's extension system could perhaps be commended to most other developing countries. In health, education and extension agencies, the 'bare-foot' Chinese doctors or the Indian community health volunteers seem to play crucial roles. In the promotion of cottage and small-scale industries in the rural areas, institutions like the Indian District Industries Centres, CSIR's Polytechnology clinics, and the State S&T Councils are potentially important. In the industrial countries, movements of the "Do It Yourself" (D.I.Y.) type are important in making people technology-minded and encouraging them to perform routine maintenance, repairs and simple technological tasks themselves.

Conclusions

In sum, the broad conclusions of this Section are that:

(i) all countries should take steps to devise proper systems for technology assessment and choice suited to their own requirements, and to institutionalise the TA process in government as well as in industry. Such systems should cover both imported and domestically developed technologies and should be related to the country's value systems, research priorities and investment policies;

(ii) the delineation of research priorities in the light of the socio-economic, security and other goals of a country should be given more consideration and emphasis than in the past;

(iii) policies to develop indigenous technology should be effectively linked with policies to set up production or other economic activities based on such know-how, to policies on technology imports, and to policies on investment;

(iv) contract research should form a major part of the activities of technology development institutions so as to orient these institutions to the needs of industry and the community;

(v) industrial pilot plants, prototype development facilities or other mechanisms for scaling-up laboratory results to the commercial level should be encouraged with assistance from appropriate design-engineering firms and government; and

(vi) extension services, productivity movements and other mechanisms for the internal transfer and diffusion of technology should be encouraged, as should the mobility of S&T personnel, in order to promote and facilitate technological change.

Section 4

Economic Policies

Economic policies (i.e. financial and fiscal policies) can play a crucial role in technological change through promoting R&D (in general or in particular), influencing the pace, magnitude and direction of change (especially in industry), and promoting new products or processes which satisfy specified social or economic criteria. These aspects are discussed in detail below.

Promoting R&D

Fiscal policies are widely used to promote investment in R&D, and to channel it into priority areas. In India, for example, under the Income Tax Act, all expenditure incurred by an assessee on scientific research can be deducted from tax liability. Likewise, any sum paid to an 'approved' scientific research association, university, college or other institution for undertaking such research can be deducted. Before April 1984, Indian income tax law had also provided for the weighted deduction of expenditure incurred by assessees on approved programmes of scientific research in priority areas, which were executed either in approved scientific research institutions or in recognised industrial R&D units. Subsequently, however, the provision was withdrawn and Indian fiscal incentives no longer distinguish between scientific research in priority areas and that in other areas. Apart from direct tax concessions, the Government exempts from customs duties all imports of instruments and equipment needed by those scientific research institutions which have not been established for purposes of profit.

A study of S&T policy instruments in 10 countries (including South Korea, India and several in Latin America)[25] found that fiscal incentives did not appear to have been very effective in inducing industrial firms to undertake S&T activities. In fact, tax incentives seem to have certain disadvantages compared with financial policies[26]. They bring unintended windfalls by rewarding people for doing things they would have done anyway; they result in undesirable inequities; they can lead to higher tax rates; and they can undermine budgetary control and public accountability. On the other hand, fiscal policies also have some advantages. Thus, compared with assistance through grants or subsidies, tax incentives interfere less in the marketplace and allow more private decision-makers to retain their autonomy; they require less bureaucracy and avoid the need to make difficult distinctions or to set arbitrary requirements for the receipt of assistance, and consequently receive a more favourable reaction from industry; they are more permanent and stable, in that they do not require annual budgetary review; and they have a high degree of political feasibility. While it is not the purpose of this Report to assess in detail arguments of the relative costs and merits of fiscal and financial policies as means of promoting innovation and R&D, it does appear that fiscal policy, if properly designed and implemented, can be a major instrument to promote and direct investment in R&D.

There are many different financial policies for supporting R&D. They include: full or partial grants by government (as in India, Japan, Italy, Singapore, South Korea, Argentina and Brazil); special funds for technological development and support activities (as in Japan, Italy, South Korea, Peru and Brazil); special credit lines by financial institutions (as in Argentina and, more recently, India); and compulsory levies on industry (as in Peru, South Korea and India).

Industrial R&D involves a complex range of activities, and until a commercial plant has been operating successfully for a period, neither industrial entrepreneurs nor financial institutions will have enough confidence to invest in or lend to an enterprise using new technology. As a result, in India, for example, almost 90 per cent of R&D finance come from the Government in the form of 'grants', with comparatively meagre returns in commercial terms. The situation is similar in other developing countries.

The expenditure required for lab-scale research, pilot plant operation/prototype development, and commercial activities, typically increases in the ratio of 1:3:10. While sufficient funds are provided in many countries for lab-scale work, the translation of the results of such research into pilot plant operation/prototype development, and commercial scale activity, is poor. Several reasons can be adduced, viz. the inadequate 'venture capital' needed to launch new technologies; an absence of schemes to underwrite possible losses or insure prospective entrepreneurs against risks; and weaknesses of indigenous design-engineering capabilities for translating the results of lab-scale work into commercial production. Analyses of the experience of industrial R&D financing policies and assessments of their efficacy show that conversion of lab-scale research into commercial activity is most effective in countries like Japan and the United States where adequate 'venture capital' is available to entrepreneurs for experimental development of commercial-level activity based on new technologies, and/or where State and other financial agencies insure the prospective entrepreneurs, fully or partially, against the possible losses or risks involved. Unless one or other of these two conditions is satisfied, the translation of the results of indigenous R&D into commercial-level activity generally remains rather poor. Finance houses fund such activity, but experience in Argentina and elsewhere has shown that the special credit lines are unlikely to prove effective unless they are underwritten or covered by loss-insurance schemes.

Influencing the pace, magnitude and direction of technological change

In addition to promoting R&D, institutional funds and bank credits can be a powerful instrument in promoting the demand for technologies, both for local and export markets, as well as in priority areas. By introducing technology-related criteria into the policies and procedures for evaluating loan applications, it is possible to use such credits as levers, influencing the pace, magnitude and direction of industries' technological behaviour. The purchasing power of the State can also be used as a powerful tool in this way.

With regard to fiscal policies, accelerated depreciation or investment allowances on new machinery or equipment based on the use of technologies which satisfy specified criteria can be used to augment production using such technologies. Indirect levies, such as customs duties and excise and sales taxes, can likewise influence the choice and use of technology.

Promoting new products or processes

In addition, fiscal and financial policies can be used to promote new products and processes which satisfy certain socio-economic criteria. For instance, to advance its socio-economic goals, a country may find it desirable to promote the introduction of, say, machinery and equipment which is more fuel-efficient or uses new sources of energy (e.g. solar), or the substitution of scarce materials, or the installation of pollution control mechanisms. Various policy instruments could be used. For example, the government could purchase equity in new industries based on the desired technology. Alternatively it could make grants or subsidies or concessional loans through its financial institutions. Appropriate fiscal policies could include direct tax exemptions for a limited period for industries fulfilling specified criteria, reduced excise duties or other indirect taxes on their manufactures; and, where relevant, reduced price controls. Such instruments are now being widely used in India and other countries to influence the direction of technological change and promote the use of products and processes which save scarce resources, to encourage the substitution of non-renewable by renewable resources, and to promote the fulfilment of many other socio-economic objectives.

Section 5

Social Policies

This section discusses various aspects of social policy, in particular those relating to the development of human resources to meet the needs of technological change. The availability of qualified, scientific, technical and managerial personnel, and the nature of their skills, are a primary constraint on technological development. Personnel may be needed at all levels of skill, from the lowest but key level of technician or operator through the middle level of supervisor and executive to the highest level of scientist, technologist, manager and entrepreneur. To promote technological change therefore, any educational system needs to cover disciplines not only in various areas of S&T but also in important related areas such as business administration, management, economics, accountancy and extension. In primary and secondary education, elementary scientific knowledge should be taught as a foundation on which higher technical, managerial and other skills are built. These elements need to be incorporated into a long-term forward-looking education plan, to take account of the long gestation of changes in the educational system, as in the technology development process. Many years may pass from the recognition of the need for personnel with certain skills to the creation of new institutions, the recruitment and training of teachers, and the emergence of their first batch of students.

In economic terms, education and training is investment in skill formation. Human resource development, however, is a much wider concept, which includes helping people to identify their particular aptitudes; encouraging and motivating them to develop these aptitudes; providing opportunities and facilities for their education and training, including informal education and retraining; and placing trained or educated persons in positions where their new knowledge and skills can make the best contribution to national social and economic development. Discovering persons who have, or who can be helped to develop,an aptitude towards science and technology, entrepreneurship, business management, accountancy, etc. should be a special task in education planning and manpower development.

The accelerated rate of technological progress will increase demands on all countries' educational systems. Inasmuch as fast changing technologies require workers and managers continually to upgrade their skills or acquire new ones, the curricula of technical education, training and management institutions need to be continuously updated. In addition, more facilities are required to provide continuing education and reorientation or retraining for people already in work. These can be provided through existing educational institutions and training facilities in factories, or through new forms of institution devoted specially to providing continuing education and retraining. In any case, it is clear that the concept of education as a formal medium-term process will have to give way to the concept of education as a lifelong process, especially in technical trades, managerial or technical skills, and even skills in social communications.

Changes in the curricula of educational and training institutions will require the reorientation or retraining of teachers or the induction of visiting lecturers to fill gaps. These tasks can be facilitated by strengthening linkages between the educational, industrial and research systems, and encouraging the mobility of personnel among them; by establishing a mechanism to review curricula; and by adopting a policy to provide sufficient funding to programmes of direct relevance to national development plans and goals. Further, to improve the effectiveness of science and technology, students' training in universities, colleges, vocational and other institutions, and the relevance of their courses to the needs of society, it may be desirable to link class-room instructions with work-experience through 'sandwich' type programmes, or require students to attend 'practice schools' in factories, or work on projects of industrial /social relevance as a precondition of obtaining a degree or diploma. Apprentice industrial training schemes are also relevant in this context.

Subjects which need to be introduced in the curricula of engineering colleges, technology institutes and other high-level educational institutions include technology forecasting and technology assessment, entrepreneurship and managerial skills. The last of these is particularly important as it is efficient management which, primarily, leads to the successful deployment of technological and other resources. All countries, and especially the developing ones, need to increase their facilities for training competent managers, by setting up more management institutes or management faculties in universities and colleges. The development of entrepreneurial leadership and associated skills is also essential, as it is the entrepreneur who catalyses the factors of production and is at the heart of development in almost all societies. Entrepreneurs obtain satisfaction by starting projects, breaking new ground, and experimenting with what may appear to be risky if rewarding propositions. Experience in several developing and developed countries has shown that through a carefully designed training programme, people can be helped to develop and improve their basic entrepreneurial traits and thus their chances of success in starting and managing new enterprises. This has been the experience of the Small Industries Extension and Training Institute (SIET) at Hyderabad in India and of the Institute for Small-scale Industry at Manila in the Philippines; other countries can provide similar examples.

In conclusion, it appears that to have the maximum impact on the promotion of technological change, any policy framework should have the following characteristics:

(i) the concept of perspective planning in education and training for technological development in order to ensure that the educational system can train people with relevant skills in a context of changing technologies;

(ii) the closer interaction between education, industry and research systems to help technical, vocational and other institutions to reorient and revise their curricula on a continuing basis in conformity with the needs of industry and society;

(iii) the increased mobility of personnel among the education, industry and research systems so as to give a more practical bias to programmes in schools, colleges and universities and to improve teachers' understanding of industry- and research-based problems;

(iv) the introduction of 'sandwich' type courses by engineering and management institutes and the adoption of other mechanisms to provide students with 'on-the-job' experience in industry or other working environments. This would greatly increase students' appreciation of practical problems and make them better suited for industry and other sectors;

(v) the provision of strengthened facilities for continuing education and retraining of workers and managers in order to reorient, improve and add to their skills for meeting the increasing demands of technological change; and

(vi) the increase in emphasis on developing managerial, entrepreneurial and associated skills such as accountancy and S&T communication.

Section 6

Environmental Policies

This section considers policies relating to technological change in the context of ecological conservation and environmental protection. All major developmental activities are almost inevitably associated with some negative environmental impacts. Environmental impact assessment (EIA) enables decision-makers to take account of the possible effects of investments on environmental quality and provides a tool for collecting and assembling the data which planners need to make development projects more environmentally sound. EIA is increasingly being applied to identify policies which achieve economic development through a more rational and sustainable use of resources.

There are two basic environmental considerations which are receiving increasing attention world-wide. One is the control of pollution, whether of land, air and water or by noise, heat and light. The other is the conservation of natural resources, particularly the non-renewable ones which will be enhausted in measurable time if their consumption continues to increase at recent rates. Past lack of attention to these matters has been responsible for environmental degradation which - unless necessary precautionary and remedial steps are now taken - could reach a point of no return, even threatening human survival itself.

Pollution control

In many countries legislation has been enacted requiring industrial enterprises (considered to be a major cause of pollution) to take necessary preventive or remedial measures to ensure that their effluents and atmospheric emissions are free (or contain less than the prescribed concentrations) of the more harmful elements and that these are discharged into the land, water, or atmosphere in a particular way. Many countries levy a tax on the volume of water consumed by water polluting industrial enterprises. The proceeds fund not only the monitoring of water and other pollution in specified locations, but also the provision of necessary supporting and administrative facilities. In the United States, for example, the Environment Protection Agency (EPA) fixes standards of purity for industrial effluents and emissions. Over the years these have become more stringent on the basis of the best standards already achieved in particular industrial sectors, and enterprises not conforming to the requisite minimum standards are penalised. In many developing countries also, legislation has been enacted allowing fines to be imposed on enterprises which fail to conform to industrial effluent and emission standards. Some countries, particularly those where legislation has been introduced only recently, promote the installation of pollution control and monitoring equipment by providing subsidies and other forms of assistance. The development of pollution control technology has been given high priority in several countries.

But it is not only industrial undertakings which cause environmental pollution. Mining and electricity generation also contribute significantly, as do municipal bodies and many larger non-industrial undertakings. Many countries now require empty pits or hollows resulting from opencast or underground mining to be filled to reduce the danger of landslides and floods. Depending on the availability of water and financial resources, municipal bodies in developing countries are increasingly attempting to construct urban drainage and sewage systems and undertake treatment of sewage before it is discharged into wastelands or water. Increasing use is also being made of urban sewage and other solid wastes as sources of organic manure. Automobiles are another major pollution source, particularly in the large urban centres of developed and developing countries. A number of countries have set compulsory standards on the emission of lead, carbon-monoxide, smoke, etc. from automotive vehicles. Likewise, many have specified standards of noise-emission from vehicles and from industrial and other machinery and equipment. Finally, increasing attention is being paid to pollution from household sources, with efforts in some developing countries to improve the quality of household fuels and to propagate the use of smokeless stoves and other non-polluting cooking devices.

In all countries where pollution control legislation has been enacted, a network of statutory, promotional and regulatory institutions has been set up to administer pollution controls. The United Kingdom, Canada, Germany (FR) and many other developed countries have such a network. Some developing countries, too, have taken steps in this direction. For instance, in India, almost all the States and Union Territories have their own water and air pollution control boards, with statutory powers to administer the relevant legislation. Separate departments of environment and ecology have been created in a majority of the States in India while an independent department of the environment has existed in New Delhi since November 1980. Central legislation to prevent and control water and air pollution was enacted in India in 1974 and 1981, respectively. However, much work remains to ensure the effective implementation and enforcement of these acts. Analytical R&D work relating to the monitoring and control of pollution is undertaken in several developing as well as developed countries (e.g. by the National Environmental Engineering Research Institute (NEERI) at Nagpur in India), while in an increasing number of developing countries pollution controls and other environmental considerations now form a part of industrial licensing and related policies.

The introduction of pollution-control legislation and related administrative machinery should be considered by all countries. Without them, there is a risk that the environment for technological development will not be sustainable in the long-term.

Natural resource conservation

It is now widely recognised that most natural resources are depletable and that in a few cases resources could be exhausted within a matter of decades. Even the exploitation of seemingly renewable resources, like forests, has been a cause of concern, particularly in countries which have not enforced laws on conservation and development. In India, for example, the forestry policy introduced in 1952 envisaged that a third of the land should be under forest. However, difficulties in implementing this policy effectively and the increasing demands of agriculture, irrigation, industries and human settlements have resulted in the forest cover being reduced to 11-12 per cent. While the use of a country's forest and other renewable resources in supplying goods and services is desirable, it is essential to ensure the long-term ecological security of a country (and of the world as a whole), by the adoption of suitable restorative, recycling and conservation policies.

It is now generally realised that the 'throw-away' culture of many post-industrial societies poses a serious threat to the conservation of exhaustible natural resources like oil and other minerals. Increasing attention is therefore being paid, especially in industrial countries, to recycling and using 'wastes' (defined as resources not utilised). In a wider sense, even water flowing down a gorge is 'waste', unless it is used to generate hydroelectricity, for irrigation, or for other purposes.

Likewise, a large part of the sun's energy is also being 'wasted', and it is only in recent years that its exploitation through photovoltaic, biomass and other techniques has been systematically undertaken and improved. More pertinent in the context of conservation policies, however,is the need for legislation (as in Germany (FR), Japan and a few other countries) under which industrial and other enterprises are required to treat or recycle certain industrial effluents or other wastes and byproducts in order to re-use the valuable components they contain. Some metals, such as iron and copper, have been widely recycled, but others (including aluminium) have not. All societies, whether industrialised or not, need to develop a 'recycling culture' consciousness, so as not only to convert 'wastes' into 'wealth' but also to prolong the availability of non-renewable resources. Increasing substitution of non-renewable by renewable resources is another strategy which deserves attention. In many countries the signs are encouraging and it seems that conservation policies may become more widespread in the coming years.

In conclusion, if technological change and development are to be sustained in the long term, countries need to devise, enact and effectively administer legislation to prevent and control the various types of pollution, and conserve and develop forestry resources, not least to help preserve the world's ecology. They also need to make increasing efforts to substitute non-renewable resources by renewable ones and attempt to slow down the consumption rate of non-renewable resources in order to prolong their availability. Finally, they should enact legislation and devise other mechanisms to promote the culture of recycling and utilising 'wastes'.

Section 7

Regulatory and Other Measures

An integrated legislative policy is a necessary counterpart of a national technology policy. Legal instruments and other regulatory mechanisms can be used to promote, permit or prevent activities, depending upon whether these are or are not consistent with technology policy. There are many such measures, and here we consider seven of them.

Import controls on goods

Most countries employ various policy instruments to control the imports of goods (and services) embodying technologies. As well as customs and revenue duties, non-tariff measures range from import prohibitions on whole sectors,to import quotas on specific goods or countries, import licences, import lists of permissible goods, and import canalisation through State agencies. By determining the types of capital goods and intermediates entering into a country, import controls have an important effect on the technology structure of local industries. They can protect these industries from foreign competition, and thus, in the short term at least, be a powerful stimulus to industrialisation. But in the long term, import controls can distort a country's industrial structure, undermine the development of its industrial S&T, and shield local industries from the need to improve the quality of their goods and the productivity and efficiency of their operations. Most developing countries have applied import controls more to consumer goods than to capital goods and manufacturing inputs, and this, coupled with their generally weak design-engineering capabilities, has meant that the development of their capital goods industries has been generally rather slow.

Technology import regulations

Most countries may prefer to import technologies than finished goods, since the latter can lead to a higher external dependency, greater drain on foreign exchange and less opportunities for local employment. However, indiscriminate import of technology can seriously undermine the growth of local technological capabilities, especially in developing countries whose newly developed technologies often cannot withstand competition from those of the industrial countries. Like infant industries, it may therefore be necessary to give locally developed technologies an opportunity to grow and become strong, before they face competition from the products of industries based on external technologies. At the same time, undue restrictions on technology imports can, as with import controls on goods, create a protected environment in which local S&T institutions and industries may have no compulsion or indeed incentive to develop internationally competitive technologies. Hence, again, restrictions on imports may have two types of effect: whereas in the short run they may protect industries based on indigenous technologies, in the long run, they can make local S&T institutions and industries complacent and incapable of achieving international competitiveness.

With regard to technology licence agreements, it is necessary to ensure that technology suppliers, often the more powerful partners, do not impose restrictive conditions on its use. This is necessary to ensure the transfer of 'know-why' and to raise the speed of the technology's absorption, adaptation and diffusion. The more important restrictive conditions that ought to be avoided in foreign collaboration agreements include:

(i) guaranteed minimum royalty payments regardless of the quantum or value of production;

(ii) restrictions on the procurement of capital goods, components, spares and raw-materials, on pricing policy and selling arrangements, etc;

(iii) restrictions on exports except, perhaps, to the technology suppliers' home-country and others where there are existing subsidiary or licensed units;

(iv) payments to technology suppliers after the expiry of the collaboration agreements except, in some cases, those related to the use of foreign patents, designs or trademarks;

(v) restrictions on sub-licensing of technology to third parties after the expiry of the agreement or, subject to mutual consent, even within its life-time;

(vi) refusal by the licensor to defend the licensee from claims for patent infringement;

(vii) restrictions by the licensor on R&D activities by the licensee or use of the results thereof during the licensing period.

Apart from the above considerations, model agreements for the purchase of technology should specifically state the principal features of the technology to be acquired, the product output, quality and specifications to be achieved, and the technical assistance to be given by the licensor, with details of the manner and timing of its provision. The agreement should also cover, as far as possible, access to any improvements made by the licensor in the technology supplied during the agreement. The licensee should insist on guarantees on the performance of the machinery, equipment and other supplies, including basic engineering services, with compensation for default. The agreements should specify the amounts of all kinds of payments by the licensee to the licensor, the duration of the agreement, the training facilities to be provided, the use of trademarks, and the conditions for terminating the agreement. Lastly, model agreements ought also to include a clause on the governing law for the settlement of disputes (which should preferably be the law of the licensee's country) and an arbitration clause with appropriate details. A large volume of literature[27-30] exists on model agreements for technology transfer and on the restrictive conditions which should be avoided in concluding such agreements.

Foreign investment controls

Most countries have laws or regulations to control foreign investment. In some of them foreign investment to set up enterprises is permitted only if it carries advanced technologies not available in the host countries. However, with acute shortages of capital and foreign exchange, many developing countries have in fact allowed foreign investment even for the manufacture of goods using relatively low-technologies. But with the growth of national identity, even these countries have increasingly regulated foreign investment. India, for instance, enacted a Foreign Exchange Regulation Act in 1974, under which foreign shareholdings of more than 40 per cent are allowed only in respect of companies whose technology is considered sophisticated or which are engaged predominantly in export-oriented manufacturing. Singapore encourages foreign investments in technology-intensive high value-added industries. A fairly large number of countries exclude foreign investment in certain industries, restrict the use of local capital by foreign concerns in some cases, have controls on restrictive business practices and foreign remittances, and so on.

The impact of foreign investment on the technologies of local industries can be very considerable. First, setting up such industries, particularly if they are based on advanced technologies, encourages competition with local firms which then have an incentive to upgrade their technological skills and standards. Secondly, in countries where governments insist on developing backward linkages with the economy through setting up ancillaries or using local supplies of intermediate goods and raw materials, technological diffusion may be promoted. Lastly, the use of technologically advanced products and the associated requirements of maintenance and repair facilities may also promote the local development of new skills.

Foreign investment, if carefully regulated, can therefore be a strong inducement for industries in host countries to upgrade their products and improve their technological skills, as well as being a powerful stimulus to technological change worldwide. However, in developing countries it is often necessary not only to protect traditional skills and capabilities, but also to restrict foreign investment to carefully identified sectors, in order to give local technological capabilities a chance to grow and develop,

Investment licensing policies

Many countries have measures for licensing new industries, particularly those which need substantial investment. Such measures fulfil a multiplicity of objectives. As the availability of investment capital is limited, especially in developing countries, many governments find it necessary to regulate the flow of investment. National plans make demand projections for goods and services required for internal consumption or export, and governments may attempt to tailor production capacities to fulfil these demands. Regional dispersal and diversification of industries and other economic activities may be encouraged and the use of appropriate, environmentally sound, and internationally competitive, technologies promoted. There are many other objectives, including import-substitution, export-promotion and employment-generation, which can be promoted with licensing mechanisms. The objects of licensing policy are, in fact, diverse and sometimes diffuse. Although the licensing and associated registration mechanisms generate much useful information, it is difficult to evaluate their impact on the management of technological change. This seems to vary according to the primary objectives and related aspects involved in the formulation of licensing policies; but it also depends on other considerations (including politics) that enter into the decision-making process. Nonetheless, licensing policies can be used to influence the pace, magnitude and direction of technological change.

Competition policy

The need for a competition policy seems to have been recognised more in industrial countries than in others. Such policies can spur industrial units into upgrading their technologies, reducing their costs, and raising the quality and performance of their products. However, whereas many countries have such instruments as anti-dumping laws, controls on the activities of large or dominant undertakings, and prohibition of restrictive business practices, few of them have adopted policies to encourage competition specifically as a way to improve the quality and efficiency of their industrial sector. Lack of a competitive environment in many countries has not only retarded the pace of technological advancement but also adversely affected the consumer interests. It is important that competition policy should take care of the above-mentioned negative aspects and, perhaps more importantly, that it should create a competitive environment for fostering technological change. This could involve the deliberate, but careful, encouragement of intra-plant, inter-plant and international competition. Both public and private sector units, particularly those at present with a monopoly, need to be subject to competition, from within and outside the country, so as to promote the greater productivity of their operations and the higher quality and performance of their goods and services. Development of internationally competitive technologies in selected sectors should be a major goal of competition policy.

Mandatory standards and norms

Technical standards and norms are a means of introducing uniformity into dimensions and other specifications, levels of quality and performance, and other parameters in goods (and services). They can also foster competition, reduce inventories, improve and diffuse technologies, and protect consumers. The last of these is particularly important for such items as food, drugs and consumer durables (especially electric appliances and cars), as well as in protection from pollution (e.g. from thermal electricity generating plants). Given their wide-ranging benefits, all countries should make more effective and widespread use of mandatory standards and norms.

Patents and trademarks

Patents and trademarks are the main legal instruments for the regulation of industrial property. A patent is a legally enforceable right granted to an entity by the appropriate governing authority, which excludes, for a defined period, others from certain acts subject to the fulfilment of conditions prescribed by the patent-holder. The concept of trademarks is well understood, and needs no definition here.

Many countries exclude specific sectors of special concern from patent laws; they often exclude atomic energy, drugs and medicines, and food. Others, however, merely grant a shorter period for patents in these sectors. In India, for instance, while patents are generally valid under the Patents Act, 1970 for 14 years, the valid period for food, drugs and medicines is only seven years. The absence of patent rights could retard the generation of new knowledge involving substantial amounts of

R&D, since, by allowing anyone to copy the patented product, the incentive for its commercial exploitation would be lost. Granting patents to foreigners and not discriminating against them (as laid down by the Paris Convention for the Protection of Industrial Property Rights) is also necessary to promote the flow of goods and technologies from patent-generating countries to others. On the other hand, most countries' patent laws usually provide for compulsory licensing if the patented know-how is not transferred by the patent-holder to any other party in the patent-granting country within a prescribed time. Compulsory licensing may also be used to avoid imports into patent-granting countries of goods covered by the patent. Finally, revocation of patents by the State can be used to compel patent-holders to license their know-how at reasonable prices to other parties. This action is specially useful where patent-holders fail to fulfil specified obligations.

The association of trademarks with particular manufacturers or distributors and with the performance and quality of their goods is widely used to promote sales, both in internal and export markets. The exhibition of trademarks can be useful inasmuch as it makes it easier to identify particular goods, especially those of certain specified characteristics. However, foreign trademarks often enjoy a psychological advantage over those of local enterprises, particularly in developing countries, which can depress the latters' sales even though their goods may often reach the standards of those with foreign trademarks. It is for this reason that some countries (including India) do not generally permit the use of foreign trademarks for internal sales.

REFERENCES

1. UNCTAD: "Technology Planning in Developing Countries"; United Nations, New York, 1979 (TD/238/Supp.1).

2. UN Dept. of International Economic and Social Affairs: "Technology Assessment for Development"; United Nations, New York, 1979 (ST/ESA/95).

3. Joseph P. Martino: "Technological Forecasting for Decision-Making"; American Elsevier Publishing Co. Inc., New York, 1972.

4. OECD: "The Measurement of Scientific and Technical Activities" (Frascati Manual); OECD, Paris.

5. UNCTAD: "Technology Policy in the United Republic of Tanzania: a survey of issues and recommendations for action"; United Nations, New York, 1982 (UNCTAD/TT/52).

6. Govt. of India, Dept. of Science and Technology, National Committee on Science and Technology: "An Approach to the Science and Technology Plan"; New Delhi, January 1973.

7. Govt. of India, Dept. of Science and Technology: "Technology Policy Statement"; New Delhi, January 1983.

8. Govt. of India, Ministry of Industry, Dept. of Industrial Development: "Guidelines for Industries - Part I, Policy and Procedures"; New Delhi, January 1982.

9. Govt. of India, Planning Commission: "Report of the Steering Group on Science and Technology and Environment for the Seventh Five-Year Plan (1985-90)"; New Delhi, September 1984.

10. Govt. of India, Dept. of Science and Technology: Annual Report, 1983-84, New Delhi, 1984.

11. ESCAP Regional Centre for Technology Transfer: "ESCAP National Papers for the UNCSTD", Vol.I: Bangladesh; Bangalore, 1979.

12. S.Y. Chia: "Foreign Direct Investment in Manufacturing in Developing Countries: The Case of Singapore", in F.E.I. Hamilton and G.J.R. Linge (eds.): "Spatial Analysis, Industry and Industrial Environment", Vol.II, International Industrial Systems; John Wiley, London, 1979.

13. ESCAP Regional Centre for Technology Transfer: "ESCAP National Papers for the UNCSTD", Vol.III: Singapore (Appendix II); Bangalore, 1979.

14. T. Geiger: "Tales of Two City States"; National Planning Association, Washington, D.C., 1973.

15. ESCAP Regional Centre for Technology Transfer: "ESCAP National Papers for the UNCSTD",Vol.II: India; Bangalore, 1979.

16. UNCTAD: op.cit.,1982 (TT/52).

17. UN: op.cit.,1979 (ST/ESA/95).

18. Meinolf Dierkes: "Technology Assessment for Developing Countries: importance, feasibility and organisational concepts" (reported in United Nations Dept. of International Economic and Social Affairs, op. cit.,1979).

19. Joseph P. Martino: op.cit., 1972.

20. Fransisco R. Sagasti: "National Science and Technology Policies for Development: A Comparative Analysis", in "Mobilising Technology for World Development".

21. Govt. of India, Dept. of Science and Technology: "Incentives for Scientific Research and Indigenous Technology - Guidelines"; New Delhi, December 1983.

22. United Nations Conference on Trade and Development, Fourth Session - Volume-III; United Nations, New York, 1976 (E.76 II. D.12).

23. UNCTAD: "Handbook on the acquisition of technology by developing countries"; United Nations, New York,1978 (UNCTAD/TT/AS/5).

24. Ibid.

25. International Development Research Centre: "Main Comparative Report of the Science and Technology Policy Instruments Project" (IDRC 109e).

26. Barry Bozeman and Albert N. Link: "Tax Incentives for R&D: A Critical Evaluation" (Research Policy 13); North Holland, 1984.

27. UNIDO: Development and Transfer of Technology Services: No.12: "Guidelines for Evaluation of Transfer of Technology Agreements";United Nations, New York, 1979.

28. ESCAP: "Guidelines for Development of Industrial Technology in Asia and the Pacific"; United Nations, Bangkok, 1976.

29. UNCTAD: "Control of Restrictive Practices in Transfer of Technology Transactions"; United Nations, New York, 1978 (TD/AC.1/77).

30. UNCTAD: op.cit., 1978 (TT/AS/5).

CHAPTER III

THE IMPACT OF TECHNOLOGICAL CHANGE ON EMPLOYMENT

AND

AGREEMENTS FOR NEGOTIATING TECHNOLOGICAL CHANGE

John Evans

European Trade Union Institute,
Brussels

February 1985

The views expressed in this paper are those of the author and do not necessarily reflect those of the Commonwealth Secretariat.

CONTENTS

Page

PART II

PART I

THE IMPACT OF TECHNOLOGICAL CHANGE ON EMPLOYMENT

I. IMPACT ON THE LEVEL OF EMPLOYMENT

Introduction

Economists have traditionally been optimistic about the long-term relationship between technological change and employment levels in general. Technological change brings about job displacement but it also brings about job creation and the conventional wisdom is that at least in the long term the latter process outweighs the former.

A quick review of the experience of industrialised countries since the industrial revolution of the 19th century would support this optimism. Despite the widespread introduction of labour-saving machinery in industrial production in Britain in the early 19th century for example, employment in manufacturing grew from less than 2 1/2 million in 1841 to more than 6 million at the end of the century[(1)]. This growth took place partly because the growth in demand for manufactured goods, both domestically and worldwide, exceeded the growth in labour productivity brought about by technological change. The benefits of technological change have not all been taken in the form of increased growth and income however. In industrialised countries working time has also fallen consistently over the last hundred years. In Britain between 1890 and 1951 the reduction in labour input as a result of reduced annual working time was equivalent to 25 per cent of the increase in

---

(1) B.R. Mitchell: European Historical Statistics 1750-1970, London 1978.

hourly labour productivity[1].

Similarly, widespread fears were expressed in the United States in the 1960s of technological unemployment arising out of automation of industrial processes. Yet, despite increased automation, employment grew from 65 million in 1960 to 105 million in 1984.

It is also clear that in the long-term the successful exploitation of the opportunities offered by technological change is a necessary condition for developing countries to raise their general standard of living.

There has been much less complacency however about what the immediate effects of technological change on employment are likely to be. In industrialised countries such short-term worries tend to come to the fore during economic recessions and recede somewhat during periods of faster growth. Thus, in the OECD countries between 1974 and 1984 unemployment increased from 3.9 per cent to 8.5 per cent of the labour force. At the same time concern had begun to mount, particularly in Europe, at the job-reducing potential of the introduction of information technology based upon microelectronics. In the Federal Republic of Germany, for example, the press in 1975 dubbed the microprocessor as the 'job killer'.

Much of the debate that has taken place in the last ten years over the employment effects of technological change particularly in industrialised countries has become polarised around the two separate views of the problem. The optimistic commentators have tended to look only at the long-term movement of economies from one equilibrium to another. The pessimistic commentators on the other hand have tended to look only at short-term displacement effects on the labour market without taking account of the possibility of compensatory effects.

(1) Sir Bruce Williams: "Long Term Trends of Working Time and the Goal of Full Employment": Paper presented to OECD Conference on Employment Growth in the context of structural change, February 1984.

A more useful approach than either of these two extremes is to consider the processes which facilitate employment adjustment, whilst recognising that the movement from one equilibrium to another may be far from easy in terms of the incidence of economic and social costs and benefits on different groups of people. As Keynes pointed out, not only are we all dead in the long run but economists set themselves too easy a task if all they are able to tell us in the midst of the storm is that once the storm is past the ocean will be calm again[1].

Economists have also shown less confidence in making optimistic predictions about the impact of technological change on the distribution of employment. It is generally accepted that the possibility can certainly exist of serious imbalances occurring either over time or between geographical regions in the relative weights of job displacement and job creation. This means that the possibility exists of certain groups of people being permanently worse off in terms of employment possibilities as a result of technological change. This was recognised by the classical economists writing at the time of the industrial revolution in Europe. Ricardo wrote in his Principles of Political Economy and Taxation in 1817:

"That the opinion entertained by the labouring class, that the employment of machinery is frequently detrimental to their interests, is not founded on prejudice and error, but is conformable to the correct principles of political economy".

---

(1) J.M. Keynes: Treatise on Money, 1930.

This section therefore addresses these two potential areas of concern, namely:- firstly, to what extent adjustment mechanisms may currently be inadequate in coping with the employment displacement arising from technological change; and, secondly, whether certain areas in the world and certain groups in society permanently lose out as a result of change.

The short term impact of technological changes

Technological change when it is applied to economic activity results in innovations both in products and in processes. New processes will normally save the primary factors of production, labour, capital and raw materials, for a given level of output in different industries. A particular innovation may also lead to the substitution of one factor for another in the production process. Product innovations are sometimes complementary and sometimes substitutes for existing products. The production of new products will also combine labour, capital and raw materials together in different quantities compared to the production of existing products. The general result of past technological change has been that the productivity of the primary factors of production has, on average, been raised.

The extent to which this development results in an increase in output or a reduction in demand for particular factors of production will partly be a result of the microeconomic mechanisms by which the potential cost savings are distributed through price or income changes. It will also be a result of the macroeconomic environment and the overall level of demand. The shape of technological change may itself affect these developments and be affected by them. For example it is generally agreed that labour-saving process innovation is more likely to have an overall negative impact on the demand for labour than product innovation. The job-creating impact of particular product innovation is, however, likely to vary over a product's 'life cycle', with a growth phase being followed by maturity and eventual decline. The extent to which job-creating product innovations come 'on-stream' is however also likely to be affected by microeconomic market structures and the macroeconomic environment.

The general conclusion is that technological innovation leads to both the creation and destruction of jobs. The balance between the two effects will determine the effect on the level of employment. In the short term at least this is not likely to be inevitable or fixed but is rather likely to be a result of the microeconomic adjustment process and the macroeconomic environment.

Market adjustment processes

Outside the centrally planned economies microeconomic adjustment takes place through a mixture of market forces and public intervention.

As seen, the most common effect of technological innovation is the increase in the overall productivity of factor inputs. The welfare gains brought about by this will be distributed differently in different national and different market situations. In a hypothetical perfectly competitive situation an enterprise would pass on all the welfare gain to the consumer in the form of a reduced price for the product being produced with the various factors. This reduction in price would then lead to an expansion of demand for the product. If the expansion in demand is proportionally greater than the increase in productivity and price reduction then, other things being equal, employment in the firm would be expected to increase. If the expansion of demand is less than the increase in productivity, then the firms' employment would be expected to fall.

The initial price reduction would also have the effect of increasing the consumer's disposable income and this could stimulate increased demand for other products and so increase employment in other sectors not connected in any way to the product undergoing technological change. In industrialised countries technological change has to some extent allowed shifts in the labour force initially from the primary into the secondary and subsequently into the tertiary sector. This has reflected the fact that, in a given sector, the displacement of labour due to technological change has not necessarily been compensated for in terms of increased demand for the output of that sector but instead price falls have allowed the increase in demand and consequently output and employment in other sectors. Since the beginning of the nineteenth century, employment in industrialised countries has shifted from the primary sector to the secondary sector and subsequently to the tertiary sector.

It is interesting to note that most centrally planned economies, in theory at least, aim to distribute the gains of technological innovation in the same way as this perfect market. As incomes are in theory fixed, productivity gains are passed on as welfare increases in the form of lower prices.

In market economies the theoretical case of perfect competition can be contrasted with the opposite extreme of adjustment to technological change in a monopoly situation. In this case the monopolist will only increase output and lower prices to the extent that variable costs may be reduced by technological innovation. If fixed costs including fixed elements in labour costs are reduced, then output will remain constant, employment may fall and all the welfare gain will be taken in the form of an increase in profit.

In the real world cases of pure monopoly are rare and cases of perfect competition even rarer. The result is that most adjustment to technological change takes place under intermediary conditions of imperfect competition or oligopoly.

The electronics industry, for example, which is at the forefront of technological innovation, is dominated by a few large general companies operating across a range of subsectors and a range of countries. There is a network of agreements, joint ventures and joint ownership links which has developed between these various groups of companies. The world computer market is still dominated by a single company, IBM, with 65 per cent of the world large computer market.

There do exist however market riches created by the proliferation of product lines which new companies can fill. Moreover in some areas barriers to entry into a market may be low. Technological innovation has spurred intense price competition in certain electronics subsectors such as production of mass-produced integrated circuits or home computers. Elsewhere however profit margins are increased and competition is muted. Corporate strategy is dominated therefore by reactions of a few competing firms to known innovations and potentially lucrative markets.

The market conditions in the industries which are involved in product innovation are perhaps less important than in those industries using new technology in new processes. Again, in many areas, the standard market structure is one of differentiated oligopoly. Under these market conditions the welfare benefits of technological innovation are neither distributed entirely in the form of price reductions nor retained entirely in the form of excess profits. The net employment effects of technological change will depend upon the relative price and income elasticities of goods and services. Moreover, changes in income and employment of different groups in society as a result of technological changes may lead to secondary multiplier effects on income, output and employment.

Certain economists have explained the economic problems of simultaneously high inflation and unemployment experienced by industrialised economies as a result of increasingly institutionalised price and wage fixing in labour and product markets[(1)]. Under these circumstances it has been argued that in response to increases in demand firms will raise prices rather than output, and so have become insensitive to government demand management policy. It would be expected that this behaviour would reduce the expansionary output and employment effects of technological change and increase the displacement effects.

These observations suggest that although over sufficiently long periods price and income elasticities in industrialised countries have been sufficiently high to ensure that technological innovation has increased employment, this cannot be assumed as an a priori inevitability in the short term. The nature of market structures in both the industrialised and developing worlds suggests that it is unsatisfactory to assume that these are automatic mechanisms whereby technological innovation will itself create sufficient extra demand to re-employ the workers displaced by it.

Adjustment and the macroeconomic environment

The process of microeconomic adjustment to technological innovation will both affect and itself be affected by the macro-

---

(1) See for example : A.M. Okun : "Prices and Quantities. A macroeconomic analysis", 1981.

economic environment. In a period of recession with uncertain expectations as to future demand growth, firms will tend to operate more like monopolists in the face of technological innovation. Innovations will be used to reduce labour costs and employment and increase profit rather than to lower prices and expand output and employment. Investment incorporating new technology will tend to be biased towards rationalisation and job-reducing process innovation rather than job-creating product innovation.

One commentator has aptly summarised the situation:- "In periods of continuous economic expansion new products may be introduced and old products displaced, accompanied by a high level of search for a variety of labour skills and a high labour demand. In zero growth situations new products may have more limited success, the search therefore intensifies for cost-reducing techniques which are not altogether compensated by investment employment and so technology is seen to be displacing labour. The deeper the recession the more serious and the more rapid the impact of technology is perceived to be upon employment and job prospects"[1].

Overall therefore it would be expected that in a prolonged recession technological change would become biased towards rationalisation and labour-saving techniques. This could help to create structural unemployment. For industrialised countries the persistence of high unemployment and high levels of unused capacity over a substantial period of time is likely to lead to a country falling into 'the low growth trap'.

---

(1) J. Goddard and A. Thwaites: "Technological Change and the Inner City", Social Science Research Council, London, 1980.

This is a reflection of the difficulties of making resources unemployed (both capital and people) and then expecting to be able to bring them back into production when needed, with no problems. The longer people and capital have been unemployed, the harder it is to bring them back into productive activity. On the labour side, a formerly skilled worker who has been unemployed for some years is unlikely to be able to move easily back into a skilled job, even if his former skills are still needed. On the capital side, after a certain period, companies are likely to disinvest and close down capacity that is unused. In macroeconomic terms in a recession, potential output will tend to adjust downwards to actual output after a time lag. So that after a period an economy may well be operating at full capacity but at a very low level production and with a high level of unemployment. In this way, cyclical unemployment is transformed into structural unemployment. There is evidence to suggest that this has taken place in a number of industrialised countries but particularly in the European economies since the late 1970s. The OECD noted that:- "... there is prima facie evidence that the rate of unemployment has risen relative to unused capacity during the 1970s. For six major OECD countries for which the OECD has made recent calculations of potential output, the apparent potential capacity shortage or the 'excess labour supply' in 1980 seems to be considerable...there has been an outward shift of curves relating rates of unemployment to rates of capacity use. If past relationships remain approximately valid, a return to full capacity use would not lead to a complete absorption of labour market slack."(1)

---

(1) OECD : Economic Outlook, July 1982, page 26.

The policy outcome of this is that an increase in investment is needed to return to full employment. Moreover, investment is required which expands capacity, is capital 'widening' and is based upon product innovation rather than investment which simply rationalises production at existing levels of output. Such an increase in investment is however unlikely to be forthcoming as long as unemployment remains high and future demand prospects remain weak. This is the nature of the trap in which a number of economies find themselves.

Examples of job displacement with specific technologies

Against this background there has been considerable concern in industrialised countries in recent years at the potential job displacement arising from new technology. Much of this has focused upon microelectronics and information technology whose impact on employment has appeared to be the most extensive of all contemporary technologies.Most industrialised countries have carried out national surveys and literature reviews[(1)]. The conclusions of these in general have been in keeping with the historical tradition of economists described at the beginning of this paper. Most official reports have been optimistic about the long-term impact of technology on employment, but considerably more concern has been expressed about the prospects for particular industries, occupations and groups in the short term.

There are obviously considerable empirical difficulties in identifying the impact of new technology on employment. Technological change is closely linked to other economic aspects

---

(1) For a Review of these national reviews see OECD, consultants' report for ICCP 2nd special session, October 1981: Stoneman, Blattner, Pastré,"Information Technologies, Productivity and Employment".

such as changes in the pattern of world trade, a changing pattern of consumer demand, changing relative factor prices and macroeconomic policy. Examining case studies of particular innovating firms or industries may overemphasize the job displacement or job compensation effect of changes. But also looking at innovating firms may miss the real impact of technology on employment because the job losses are likely to occur in non-innovating firms or countries which suffer a loss of competitiveness.

Despite these qualifications, it is worth noting that there is considerable prima facie evidence of quite extensive job displacement in industrialised countries over the last decade which is associated with technological change.

Microelectronics

In industrialised countries, and particularly in Western Europe, the impact of microelectronics can be seen to have displaced labour in three main areas over the last ten years.

The first area of job displacement has been in those industries manufacturing products in which mechanical or electromechanical elements have been replaced by microelectronic elements. In some cases this has resulted in a dramatic transformation of particular products. The industries affected include large parts of electrical equipment manufacturing such as telecommunications equipment, cash registers, calculating equipment, business equipment; it also includes precision tools and watches.

In these sectors the application of microelectronics has resulted in a reduction in the number of components of the final product and consequently the amount of assembly work involved in manufacturing them. Standard Electric Lorenz produce an electronic telex machine in which one microprocessor has replaced 936 separate parts in its electromechanical predecessor. Electronic watches, are assembled from five basic components - a battery, quartz crystal, light emitting diode, integrated circuit and case. This is compared to the thousand manual operations involved in manufacturing a mechanical watch. Even allowing for a large expansion of production in some of these sectors, this has not been sufficient to provide employment growth and in some cases to avoid the loss of jobs. An OECD survey of the electronics industry has reported that: "employment in the majority of the United States electronics firms has not increased during the 1970s, whilst real output has risen considerably and sales revenue even faster...Employment trends in European firms followed the United States pattern".(1) One such company affected - the Italian firm Olivetti - carried out a survey of a number of companies producing mechanical and electronic business equipment products. The eight companies surveyed reduced their employment by 20 per cent during the 1970s, whilst undertaking transformation of their production systems away from mechanical and towards electronic production. The Swedish telecommunications equipment manufacturer, Erickson, reduced its production employment from 15,000 to 10,000 between 1975 and 1978 as a result of a changeover from producing electromechanical to electronic and semi-electronic telephone switching systems. In the countries of the European Community employment in electrical engineering fell by 338 000, or 14.2 per cent, between 1974

---

(1) Science and Technology in the New Socio-Economic Context, OECD 1980. Sector study on electronics by Mick Mclean, University of Sussex.

and 1982. Employment in the manufacture of data-processing machinery and office equipment fell by 28 000, or 10.6 per cent, during the same period.

Technological changes in the electronics industry have also been combined with significant changes in the international location of production activities. All parts of the industry, with the exception until recently of telecommunications equipment manufacturing, have become highly internationalised with a tendency in many sectors for companies to locate labour intensive parts of production in low cost parts of the world such as the Far East, whilst retaining research and other activities close to their home base. A survey of the major US companies involved in integrated circuit manufacture(1) estimated that between 1974 and 1978 these companies increased their US semiconductor employment from 85,000 to 90,000, whereas overseas employment grew from 70,000 to 90,000 over the same period.

Probably the largest impact of microelectronics on employment in developing countries in the last ten years has been the growth in offshore assembly plants of US and Japanese electronics companies in newly industrialising countries. The expansion in employment in these plants has reflected a redistribution of world employment when the substitutive effects of microelectronics in industrialised countries are taken account of.

The second area of technology-related job losses has been where microelectronics has allowed a marked change in the production process. This has been primarily felt in industrial countries. Perhaps the best example has been in printing where microelectronics has allowed a changeover from hot metal to computerised typesetting, and this has had significant employment effects. In the E.C. countries employment in the printing, publishing and paper industry fell by 255 000, or 12.7 per cent, between 1974 and 1982. Jobs involving typesetting and graphical skills have been replaced by jobs involving data entry and data analysis.

---

(1) U.S. International Trade Commission: quoted in United Nations Centre on Transnational Corporations (CTC) study on "The International Semiconductor Industry",1983.

Microelectronics is particularly suitable in automating industrial processes where existing jobs involve tasks which are repetitive or sequentially repetitive. An example of such an application is the development of robotics, in which straight substitution of human by mechanical activity takes place. Whilst the main use of robots up to now has been in the mass production industries, such as motor vehicles (where the majority of American, European and Japanese producers have introduced robots), metalworking, chemicals, civil engineering, electrical and electronic industries, their use will expand over the next ten years into wider fields of application.

The main tasks carried out by robots are those of assembly, joining and handling. A major American manufacturer of robots has estimated that 50 per cent of the machines it has installed have been used for spot welding, about 11 per cent for dye-casting and another 5 per cent for machine loading. With advances in the application of microelectronics, particularly in science or technology, universal machines are being developed which are able to carry out more complex assembly tasks.

A study on the introduction of robots in the Federal Republic of Germany(1) examined the introduction of ten robots in five companies in a variety of sectors. The tasks affected were arc welding, paint spraying and handling of pieces. The effects on manning requirement were that a total of 46 people in non-qualified jobs were affected; of these 7 were made redundant, 28 moved out of the sector, 10 changed jobs within the sector, and one moved into the sector. The introduction of robots therefore meant substantial labour displacement. In the British motor industry British Leyland has used robots

(1) Battelle Institute, Frankfurt.

in its Mini Metro production line at Longbridge. Twenty-eight robots are used, with a high degree of central computer control. Only 38 workers are employed on car body assembly compared with 138 who it is estimated would be required on a conventional production line.

The third example of the job displacement effect of the application of microelectronics has been in the service sector. Microelectronics is resulting in the 1980s in the application of electronic data-processing more widely across the service sector in industrialised countries, allowing the automation of many office and distribution jobs. This is already resulting in a slowdown in employment growth in services such as banking and insurance, which have become important users of computers in the last ten years. In the 1960s employment in banking and insurance grew rapidly in most industrialised countries. In Europe growth was most spectacular in Belgium, where it averaged 10 per cent between 1964 and 1974. In France and Denmark annual employment growth was more than 6 per cent and in Germany and the UK more than 3 per cent. Between 1974 and 1982 growth had slowed substantially,to 1.3 per cent in Belgium, 1.6 per cent in Denmark, 2.0 per cent in Germany, 2.1 per cent in the UK and 2.7 per cent in France. This had been at the same time as a continuing growth in the demand for bank services.

Biotechnology

There has been less of an obvious impact on employment arising from the diffusion of other key technologies in industrialised countries over the last few years such as biotechnology, new forms of energy and new materials. Biotechnology may have an important impact in the future on industries such as agriculture, food manufacturing, petrochemicals, pharmaceuticals and water supply in both developed and developing countries. However, its impact to date has been limited and it has not been developed to a stage where it has led to widespread production process innovation. An OECD report on the pharmaceutical industry in 1980 found that "until recently, the increase in staff resulting from higher production, greater activity abroad and the need for additional manpower to carry out new tests and other operations (metabolism, metagenesis, volume of data to be collected) has compensated the reduction due to gains in productivity and, in some cases, due to mergers or acquisitions. This comparative stability is today threatened by the deterioration in the economic situation and a deliberate policy of cutting down on staff members."(1) Firms did report increases in productivity due to technical progress in fermentation processes, in the production of chemical substances and in packaging, but recorded lower increases in general productivity than in the past. Any technologically induced changes in employment displacement have therefore been swamped by the effects of the recession.

The potential uses of biotechnology in the field of developing health applications such as new drugs and pharmaceutical products would seem to point the way to substantial production developments. Although such developments are unlikely to be highly labour-intensive once at the application and production stage, they should provide some source of employment growth in the medium-term, having primarily expansive rather than substitutive effects on employment.

In agriculture and the agrofood industry biotechnology may certainly lead to important product and process innovations. These may have important structural effects on the livelihood of those in the agricultural sector, particularly in developing countries. The EEC's Fast Team has warned that "while biotechnology offers new and valuable strategic options, it also inevitably threatens by substitution many established crops and activities, particularly if they currently command a high price".(2)

(1) Science and Technology in the New Socio-Economic Context, OECD 1980. Sector study on pharmaceuticals.

(2) EEC: "The Fast Programme, Vol.1, Results and Recommendations, 1982.

An example is the case of isoglucose which is an effective substitute for sugar produced from starch using an inexpensive process originally developed by European firms. Outside Europe isoglucose production has expanded rapidly using starch derived from maize in North America and manioc in Japan. In Europe, however, its production has been limited through levy and quota restrictions with the aim of protecting European beet sugar producers. The protectionist option has not been open to cane sugar producers in developing countries, whose export earnings have been affected both by isoglucose production and by protection of sugar beet in Europe. The EEC's FAST team have said, somewhat idealistically, that coping with the structural impact of biotechnology "... demands sensitive management which assesses the value of competing technologies and permits a proper balance of interest to be struck, for example between the interests of 'isoglucose' manufacturers, sugar beet farmers, the citizens of Europe, and the Third World producers of cane sugar; or between the manufacturers of single cell protein and the importers or growers of conventional animal feed (or human food)."

The exact impact of biotechnology upon food production is a matter of conjecture. However, given earlier analysis of this paper, it is a matter of concern that the markets for processed food in most countries are dominated by a few large multinational corporations. This would tend to restrict the advantages to the consumer of technological changes. Some of the impacts with regard to developing countries are returned to later.

Energy

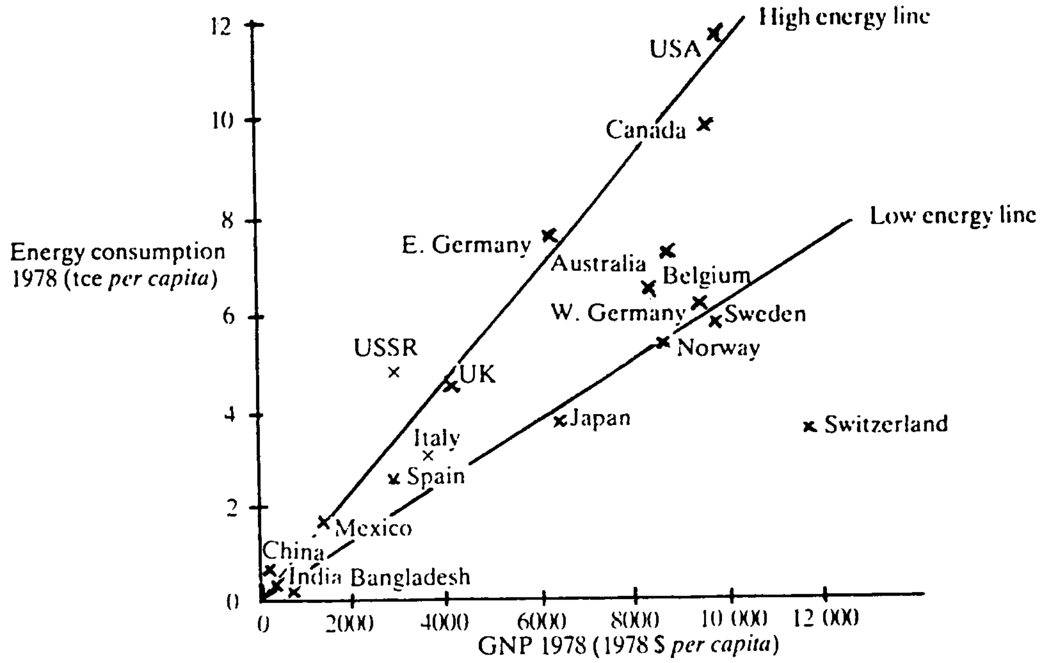
Energy technology will also have a key impact on employment in general in the future, although the issues at stake cover far wider questions than substitution effects between existing and future energy sources and questions of labour displacement. In the past, the substitution of one energy source for another has clearly had major displacement effects.

In the 1880s coal overtook wood as the main energy source in the United States, something which it had already done in the industrialising European countries. Employment in the coal mining industry grew rapidly in those countries to an historical peak in the mid-1920s. In the 1880s coal mining employed more than half a million people in Britain and Germany, 200,000 in France and 100,000 in Belgium. By the mid 1920s the figure had risen to 1.4 million in Britain, 1.2 million in Germany, 450,000 in France and 200,000 in Belgium. In 1982 the employment in coal mining had fallen to 270,000 in Britain, 190,000 in Germany (Federal Republic), 59,000 in France and 23,000 in Belgium. During the period following the Second World War oil surpassed coal as the main source of energy worldwide and currently accounts for some 45 per cent of the world's commercial energy supplies.

Fossil fuels are still overwhelmingly the most important source for world electricity supplies. However, the oil price rises and supply problems of the 1970s have raised fundamental questions about long-term availability of existing fossil fuels. Most industrialised countries have embarked upon major programmes for nuclear energy, although these still represent only a few per cent of world energy supplies. Moreover, nuclear programmes have been beset with problems of very high capital costs, considerable technical difficulties and major safety and environmental problems. Alternative energy sources, such as wind, wave, solar and biomass, are quantitatively insignificant in terms of world production.

The future choices of energy technology will clearly have a direct impact upon employment patterns in those industries. More importantly however is the fact that they will reflect the energy intensiveness of future patterns of growth. Vast differences exist between the industrialised countries and developing countries in commercial energy consumption per capita. Thus, in 1947 the United States, with only 6 per cent of the world's population, consumed 47 per cent of the world's commercial energy supplies. That of the developing countries has however been increasing, partly due to increasing per capita use and partly due to increasing population. By 1974 the United States' share of world energy consumption had dropped to 30 per cent.

Energy use also varies between industrialised countries with the same level of income per capita as can be seen from the chart below. This suggests that considerable scope exists in reducing energy consumption for given levels of industrialisation.



<u>International comparisons of energy consumption per capita and GNP per capita</u>

<u>Source</u>: The World Bank, World Development Report, 1980.

These questions will continue to dominate energy policy discussions during the 1980s and are far from resolved. The British House of Commons Select Committee on Energy reported in 1981 that: "we were dismayed to find that, seven years after the first major oil price increases, the Department of Energy has no clear idea of whether investing around £1,300 million in a single nuclear plant (or a smaller but still important amount in a fossil fuel system) is as cost-effective as spending a similar sum to promote energy conservation."

Choices between high or low energy consumption strategies have important implications for employment. For example, in the UK considerable scope for savings of energy use exists in the housing sector. Investment in insulation, draught proofing and heating controls would have substantial rates of return when viewed in terms of the long-term benefits of energy conservation and the short-term opportunity costs of carrying it out. Compared to building new power stations, energy conservation measures have short lead times, are less capital intensive and have a shorter period of state financial commitment. They also employ relatively unskilled labour and provide jobs in urban areas, where unemployment is highest. Proposals have been made for full-scale national insulation programmes which would create jobs.

For developing countries the choice of energy consumption strategy is even more crucial, in that labour is generally plentiful and energy generally scarce. Future energy requirements and the future energy sources are closely related to the choice of technology throughout the economy rather than simply in the energy sector. The question of the choice of appropriate technology is returned to later.

New materials

Technological change in products and processes also affects the demand, output and hence employment in industries processing and extracting the materials used in those products and processes. For certain developing countries which depend greatly upon particular commodities for their export earnings, substantial shifts in demand and prices can have profound domestic effects.

One of the clearest examples of a material whose demand may be substantially affected by technological change is copper. The major part of the world's output of copper is used by the electrical, electronics and telecommunications industries. Within these industries copper has been used as the main electrical conductor, in the form both of insulated copper wire and of bare copper strip incorporated in electrical circuits and equipment. Copper strip is also used for manufacturing stampings and printed circuits. These uses have already been influenced by technological change. The development of micro-electronics and use of integrated circuits has vastly reduced the quantity of external wiring used for a given quantity of electronic circuits. More importantly the development of satellite communications and fibre-optic cables has the long-term potential of reducing substantially the use of copper in telecommunications. To some extent these effects have been offset by the expansion in output of the electronic and telecommunications sectors. But it is clear that widespread reductions in the use of copper could have drastic effects on those countries, all developing countries, which are heavily dependent upon copper exports for their foreign exchange, government revenue, and employment.

Is there a permanent shift to labour-saving technological change?

The preceding sections have given some support to the view that in the recessionary environment of the late 1970s and early 1980s technological innovation based upon microelectronics had some labour-saving bias, which contributed to problems of capital shortage and structural unemployment, particularly in Western Europe. In terms of policy implications it is important to know whether this has permanently changed production functions in certain countries or whether the labour-saving bias of technological change would be reversed in a period of sustained and rapid economic growth.

In terms of achieving policy goals of raising employment a general capital-saving bias in technological change can be seen as a blessing whereas a labour-saving bias increases the potential problems of structural unemployment. As pointed out earlier, according to the product life cycle theory the labour-and capital-saving biases of a particular innovation are likely to vary over the product's life. If technological innovations are bunched over time rather than being evenly distributed, then this would be likely to have macroeconomic effects. Waves of technologically-induced job creation could be expected to be followed by waves of job displacement and decline.

In the 1920s Kondratiev[1] attempted to show that such long-term economic cycles or long waves existed, and later Schumpeter[2] argued that variations in the rate of technological change could explain these long-term economic cycles. He argued that the development of certain key technologies as opposed to improvements in technology could stimulate a period of employment growth. As examples of such technologies he gave steam power, railways, electric power and the automobile. However, at a certain point in the cycle the labour-displacing effects of the technology could be expected to outweigh the employment expansion, and the economy could move back into recession. A number of recent commentators, notably Freeman[3], have gone on to claim that the

(1) N. Kondratiev: "The Major Economic Cycles", 1925.

(2) J. Schumpeter: "Business Cycles: a Theoretical Capitalist Process", 1939.

(3) See, for example, C. Freeman: "Long Waves in the World Economy", 1982.

growth of the electronics industry and information technology represents just such a feature of the long wave, and can be compared to the earlier innovations mentioned above. The exponents of this view argue that the expansion of employment in the electronics industries and in data processing in the industrialised countries during the 1950's and 1960's has now been replaced in those countries by a downturn in the cycle with displacement effects in other industries replacing growth in electronics. As seen in earlier sections, employment in the electrical industries as a whole has been constant in the United States and has fallen over the last ten years in Europe.

The statistical basis of the existence of long waves in capitalist, industrialised economies is far from unequivocally accepted. However, even if the long-term business cycle has occurred historically,this does not necessarily imply impotence in coping with its current manifestations. Technological innovation is not solely exogenous to socio-economic developments and therefore is itself partly determined by the economic cycles, which it may be a factor in stimulating. The fact that, in historical terms, significant periods of technological innovation have coincided with periods of rapid growth in demand and output, does not therefore on its own indicate causality. In explaining past cycles of economic activity, however, the 'bunching' of technological innovation may provide a better explanation of some periods of upturn and downturn than a straightforward explanation of multiplier accelerator interaction. However, again in the long-term, the influence of government policy in both developing and industrialised economies cannot be ignored and in the future this may well have a more significant influence upon the nature and timing of economic development than either exogenous technological developments or the internal mechanics of the trade cycle.

Nor can the activities of the major actors in the process of technological change be ignored. For example, it has been shown that the level of working time has fallen steadily in industrialised countries over the last hundred years.

This has been a way of exploiting the advantages offered by technological change. Between 1950 and 1970 30 per cent of productivity growth in OECD countries was taken in the form of reduced working time. This was in the main the result of pressure by trade unions of working people who succeeded in reaching agreements with employers or in getting legislation passed limiting working time. Pressure has mounted, particularly in Western Europe, to accelerate the process of reducing working time. If the labour-saving bias of technological change is maintained, then this may increasingly have to become part of government policies in industrialised countries.

Conclusion on the efficiency of adjustment processes

The foregoing sections therefore argue against taking a deterministic view of the impact of technological change on the level of employment. However, they also argue against complacency. Given the real world of inadequate market adjustment mechanisms and an uncertain macroeconomic environment there is a very real danger that in industrialised countries the potential advantages offered by technological change will lead to increased structural unemployment in the short and medium term rather than to increased human welfare. This is not inevitable however, and can be countered by appropriate policies by the major actors involved in technological change. As will be argued in a following section, the problems facing developing countries are of a much greater order of magnitude.

The possibility of long-term regional disequilibria

The existence of compensation effects although inadequate does give some grounds for general long-term optimism about the impact of technology upon employment. However, economic theory gives no assurance that the employment creation effects of technological change will in the long term compensate the same region or country or group of people whose jobs are displaced as a result of that change.

This is particularly so since the world economy has become increasingly interdependent through the expansion of world trade since the Second World War. Its dominant feature has become the widening gap in living standards between the developing countries and the industrialised countries. In the long term improving living standards and achieving economic development depend upon the twin processes of capital accumulation and technological innovation, which are closely related. As seen in industrialised countries, technological innovation is the result of the introduction of new technologies based upon the outcome of research and development. Developing countries have much less potential for influencing technological change themselves, since 97 per cent of the world's R&D takes place in industrialised countries. They therefore have to rely primarily upon adapting old technologies already in use in industrialised countries or new technologies currently being developed in those countries.

This situation presents three sets of issues for developing countries. Firstly they are dependent upon a process of technology transfer from industrialised countries. The most important medium in this process are multinational corporations with home bases in industrialised countries. Clearly, to obtain technology through such transfers gives developing countries an opportunity to acquire technology which was not open, for example, to European countries going through the industrial revolution in the nineteenth century. However it also means that the developing country does not always have the possibility of moulding the technology to its needs. This raises a second set of issues: that the technology which is imported may not be appropriate to the resource endowments and development needs of the developing country. Thirdly, the country's potential for assimilating technological change will tend to be much less than in industrialised countries. Rapid technological change may therefore lead to a widening of the technology gap between industrialised and developing countries rather than a narrowing of it.

It would be wrong, however, to exaggerate the homogeneity of either industrialised or developing countries with regard to their technological capability or the future impact of technological change upon them. There are more successful and less successful industrialised countries in terms of their technological performance. There are much greater differences between developing countries in terms of their degree of industrialisation, their basic infrastructure, their resource endowment, the export orientation of their industry, their population and the general diffusion possibilities for new technology. For example, 80 per cent of all capital goods production in developing countries takes place in only eight countries.

Various studies have been carried out which, by making generalisations about groups of countries, have allowed some insight to be gained as to the potential impact of technological changes in the future upon employment and income in those groups. For example, Cole[1] has examined the impact of microelectronics upon four different groups of countries:- the technology dynamic industrial economies; the less dynamic industrial economies (which include Australia, Canada and the UK); the newly industrialised economies, NICs (including Hong Kong and Singapore); and the least-developed economies (which include most Commonwealth countries). The study compares a trend scenario in which developments experienced during the period 1965-1975 continue with the scenario of what the author calls a 'microprocessor revolution'. In this scenario aggregate productivity has the potential to increase by a factor of two in the service and industry sectors. However, the implementation differs according to the group of countries, with relatively rapid implementation

---

(1) Sam Cole: "A Microprocessor Revolution and the World Distribution of Income: A General Equilibrium Approach", International Political Science Review, Vol.3, No 4, 1982.

in the dynamic industrial economics and little adaptation in the least developed countries.

The results of the simulations highlight the large scale of changes and the fact that "the links between economies via world markets ensure that even in economies not undergoing more rapid technological change absolute income and distribution of income are substantially changed"[1].

The countries that gain most from this 'technological revolution' are the NICs,with higher employment and income growth than under the trend scenario. However, they also become increasingly technologically dependent, and the report by Cole notes that "the imperative for these economies to adopt the technologies must compromise their negotiating position with respect to the main carriers of technology, the international firms".

In the least developed countries, however, income and employment of the higher skilled groups in the labour force is substantially lower than in the trend scenario. The lower skilled groups do somewhat better, but only because the slower growth of the industrial sector and a less competitive world food market means that there is less movement from agriculture into the industrial sector. In the industrialised world the more dynamic countries do substantially better in the new scenario than do the less dynamic. In the latter group the income and employment of the less skilled groups in the labour force is lower with the 'microelectronics revolution' than under the trend scenario.

The above results obviously depend on the assumptions of the model. For example, they ignore the adjustment processes in change. They are important, however, in indicating the distribution of gains and losses on a world scale arising from

(1) Ibid.

faster technological change of the type described. They show that under the assumptions made in an open world trading environment the gains from a 'microelectronics revolution' are unevenly spread. They do not however give credence to the views which have been expressed that the widespread adoption of microelectronics will undermine the export-oriented strategies of the NICs by changing their comparative cost advantage. Nor do they support the view that microelectronics will offer most developing countries the opportunity to "leapfrog" the industrialisation process and rapidly close the gap in income with the industrialised countries. These conclusions are however a result of assumptions in the model,and more substantive issues are discussed below.

The impact of technological change on comparative advantage

The argument has been put forward[(1)] that the increased automation made possible by microelectronics will reduce the importance of direct labour costs in total costs in certain labour-intensive industries which are highly important in developing countries which have pursued export-orientated growth strategies. It is suggested that this will reduce the importance of developing countries' comparative advantage in terms of labour cost and lead to a return of formerly labour-intensive production back to the industrialised countries, which have greater advantages in terms of management techniques, coordination and marketing. The industries commonly cited as being most affected are textiles, clothing, footwear and parts of the electronics industry. In the words of King, "... automation in the North is bound to erode the comparative advantages enjoyed at present by the low labour cost countries of the South"[(2)].

(1) See for example J.Rada: "The impact of microelectronics", 1980.

(2) A.King: "Microelectronics and World Interdependence",in Friedrichs and Schaff (eds.): "Microelectronics and Society For Better or For Worse", 1982.

It is certainly true that in the clothing and textiles sectors considerable research effort is being focused in the field of automating labour-intensive processes. For example, in the United States textile manufacturers are spending $2 billion per year on automation. In the EEC countries the European Commission has sponsored a basic research programme for automation in clothing manufacture, which combines together the main clothing manufacturers as well as machinery producers and manufacturers.

In the electronics sector the major international companies have rapidly increased their employment in the NICs, whereas employment in industrialised countries has grown little or has fallen. This has not just been the case in consumer electronics but also in electronic components. The share of labour costs in total production costs for integrated circuits varies in the different stages of production. In chip fabrication, labour costs form 18 per cent of the total costs, in the chip assembly they form a third of total costs and in testing 75 per cent of total costs. It has been assembly and testing activities which in the main have been the target for relocation to low wage developing countries and for automation. Given the relatively low start-up costs of off-shore assembly and testing plants and the variation in wage rates shown in the table on the next page, it is clear that overseas investment by semiconductor multinationals can be extremely volatile.

<u>1980/81 average industrial hourly wage rates in selected countries with semiconductor assembly plants</u>

United States	$8.09	Mexico	$1.54
Belgium	$7.91	Hong Kong	$1.26
Federal Republic of Germany	$7.16	South Korea	$1.10
		Singapore	$1.00
Netherlands	$6.96	Taiwan	$0.90
France	$6.14	Philippines	$0.62
UK	$5.92	Indonesia	$0.45
Ireland	$5.16		
Italy	$4.63		

<u>Source</u>: "Electronics", quoted in Global Electronics Newsletter, No 21, April 1982 and Eurostat for European figures.

It would be wrong, however, to overemphasize the likely effects of changes in comparative advantage on employment in the developing world. Labour costs have not been the sole determinant of the pattern of world trade, employment or investment. Other factors such as raw materials, energy, markets, geographical location, government polices are just as important. Indeed, one recent ILO study has even gone so far as suggesting that labour costs are relatively unimportant in determining multinationals' investment decisions. The study concludes that: "... local wage levels do not play any significant part in the technological choice made by MNE (multinational enterprise) subsidiaries and that government legislation on minimum wages, contrary to what was often assumed, does not appreciably accelerate the shift to more capital-intensive technology in the enterprises"[1].

In some NICs, such as Singapore, government policy has deliberately attempted to raise the level of real wages and the level of skills

---

(1) "Technology choice and unemployment generation by multinational enterprises", ILO, 1984.

of the labour force to move to the higher technology areas of production. A greater problem indicated in the simultations referred to above is one of increasing technological dependence of the NICs. The nature of investment carried out by multinational companies may limit the extent to which a transfer of technology can be integrated into the structure of the economy. In electronics,for example,one commentator has noted that: "semiconductor assembly is based on a technology bearing virtually no relation to that required in the various front-end semiconductor processes like circuit design, mask generation and wafer fabrication. Hence, the transfer by semiconductor firms of their assembly operations to developing countries has not enabled those countries to develop fully integrated semiconductor industries"[(1)].

Some commentators do not share this assessment and have argued that the experience of some NICs, such as Singapore and South Korea, has shown that strategies can lead towards the development of integrated production activities in certain product categories. Indeed the question has been asked as to whether the development of integration *per se* is a necessary goal for developing countries to pursue. It is undoubtedly true that the NICs have managed to raise their income and development levels through export oriented strategies. These strategies, in their first stage at least, were not aimed at the development of integration industries but at benefiting from specialisation and comparative advantage. An issue of importance is the extent to which NICs, having achieved initial development through specialisation and export orientation, can successfully move into the development of indigenous industries and less labour-intensive activities.

---

(1) D.O'Connor: "Global Trends in Electronics: Implications for Developing Countries", World Bank, 1983.

A second issue of importance is the extent to which the export-oriented industrialisation strategies which have been followed by the NICs can be usefully adopted by other developing countries. Without denying that important lessons can be learned from the NICs' experience, it is also true that the majority of NICs have been small countries which have benefited from natural advantages, and a judicious balance of government policy and exploitation of international market developments. The OECD, in reviewing the experience of NICs, has warned that "outward-looking policies may, in some instances, result in unbalanced growth, over-emphasising directly productive as opposed to infrastructural investment, and industrial and urban over agricultural and rural development. They may also favour an uneven distribution of incomes, limiting domestic absorption. As development proceeds, there will be a need to raise the share of urban and social infrastructures in total investment and reduce inequalities of income distribution between sectors and income categories."(1)

"Bypassing industrialisation"

Some commentators have argued rather optimistically that technological advances, and in particular microelectronics, give developing countries the possibility to bypass the industrialisation process and 'leapfrog' into a position of higher growth and development. To quote one critique of such views: "the argument is a strange anagram of rhetoric that borrows from notions of self-reliance, basic needs, appropriate technology and modernisation, combined with an imaginative, though

---

(1) OECD:"The Impact of the Newly Industrialising Countries", 1979.

unrealistic, interpretation of the development process[1].

As seen, economic development depends as much upon the process of capital accumulation as upon technological innovation. If the evidence reported earlier is correct, that microelectronics-based innovation is currently incorporating a labour-saving bias, then this could have the opposite effects of those mentioned above and aggravate the already large problems of capital shortage and underemployment in developing countries.

Perhaps, more importantly, the evidence suggests that even if capital shortage is not a problem, the large majority of developing countries will have severe difficulties in applying current technological change due to shortage of labour skills and a basic technological infrastructure. One commentator has noted that: "the important point with respect to electronics is that the advantage of an abundance of technically trained labour power and a strong indigenous scientific and research infrastructure may more than offset the disadvantage of a relative shortage of capital for a particular developing country"[2]. It is, however, these very factors that the majority of developing countries lack.

It is also doubtful to what extent some technology developed in industrialised countries is directly relevant to developing country needs. The 'Green Revolution', for example, by helping to increase rural inequality and create an unskilled agricultural labouring class, appears to have exacerbated agricultural problems in some developing countries, rather than solving them. The same may be true of the application of microelectronics. The danger exists of both the electronics producing and using industries acting as a useless and costly

---

(1) Atul Wad: "Microelectronics: Implications and Strategies for the Third World", Third World Quarterly, No 4, 1982.

(2) D.O'Connor: "Global Trends in Electronics: Implications for Developing Countries", World Bank, 1983.

accessory to the main development requirements of developing countries. The report by O'Connor argues: "the electronics industry of a developing country can only contribute substantially to the broader process of industrialisation when it is fully integrated into that process. By grafting an electronics industry onto the immature sapling of an underdeveloped economy one does not thereby ensure the growth of a sturdy trunk from which will branch out a diverse yet closely intertwined array of thriving industries"(1). Here the importance of integration into the rest of the economy is emphasised rather than the integration of the electronics industry itself.

Undoubtedly, certain innovations may prove of great value in meeting developing countries' needs. For example, remote sensing by satellite provides new sources of information with regard to raw material deposits and land use. The key issue, however, is whether such information is made available to developing countries or whether it remains in the hands of private corporations and is simply used to strengthen their negotiating position with the developing countries. Even if information is made available freely to developing countries, the question remains of whether they possess the infrastructure to use it in practice.

National technology policies

In the longer term it is clear that countries can influence the impact of technology upon them and can widen the spectrum of technological choices available to them. To this end, national technology policies can play an important role as part of overall development policies. In conclusion, it is worth restating UNCTAD's suggestions for the ingredients of national technology policies. These should include:

- Unpackaging of technology (i.e. splitting imported technology into smaller units, some of which may be able to be supplied locally);

---

(1) D.O'Connor: 1983, op.cit.

- Adapting and developing imported technology for domestic use; hiring design and engineering consultants to help with the choice and use of imported technology;

- Ensuring the supply of accurate information to governments and technology users on choices available and how to utilise them;

- Ensuring standardisation and quality control; promoting appropriate education and training (particularly scientific and technical education);

- Fostering demand for domestic technology, particularly pursuing policies which produce a more even distribution of income which in turn stimulates demand for basic foods, clothing, housing, etc. rather than high cost luxury imports;

- Finding an effective role for public sector enterprise;

- Exerting influence over the private sector (through measures such as financial policy, taxation and investment incentives, trade policy and import sustitution efforts);

- Providing finance for technology development (e.g. through levies on industrial turnover or special taxes);

- Coordinating different technology policies and the institutions for implementing them.

II. IMPACT ON THE QUALITY OF WORK

The quality of work

Defining or measuring the qualitative aspects of work is a highly subjective process. Nevertheless, in practice people do make judgments about satisfying and dissatisfying aspects of work and considerable experience has been built up in analysing what determines job quality. This suggests that the main determinants of job quality are: job content; its meaningfulness; the learning involved; working environment; job security; social contact; rewards; and the impact upon leisure time. Important factors affecting job content include the skill requirements, the responsibility, the freedom from supervision, the control over work pace. In determining a job's meaningfulness it is important for a worker to see the role the job plays in the overall production process and see its relevance to the final product.

A superficial review of the nature of work in both industrialised and developing countries suggests that outside of small elites few people have genuinely high quality jobs. Even in the industrialised countries, where life expectancy, education and income are all far higher than on average in the developing countries, the majority of working people have unsatisfactory working environments. A survey carried out in the Federal Republic of Germany[1] in 1981 found that:

---

(1) H.Hennings: Arbeitsplätze mit belastenden Arbeitsanforderungen, in Mitteilungen aus der Arbeitsmarkt und Berufsforschung, 4, 1981. (Percentages are of total employed population).

- 6.4 million employees (29 per cent of the total) were exposed to high levels of noise;

- 6.2 million (28 per cent) worked according to tightly defined procedures and schedules;

- 5.2 million (24 per cent) worked in an excessively wet, cold, hot or draughty environment;

- 4.2 million (19 per cent) worked in a physically uncomfortable position;

- 4 million (18 per cent) were exposed to hazardous environmental factors such as smoke, dust, gases;

- 3.8 million (17 per cent) were required to use considerable physical effort;

- 3.1 million (14 per cent) were engaged in night and shift work.

Another German study[(1)], undertaken in 1977, estimated that 33 per cent of men and 46 per cent of women employed carried out repetitive jobs with low responsibility, whilst 11 per cent of men and 40 per cent of women carried out jobs involving simple auxiliary tasks. Despite these factors, the FRG is often described as one of the industrialised countries with rather better working conditions.

It is against this background that a debate has developed in the industrialised countries over the impact of new technology, and especially microelectronics, on the quality of work.

---

(1) European Foundation for the Improvement of Working and Living Conditions: "New Forms of Work Organization in Western Europe", 1979.

Quality of work in developing countries

Questions of the quality of work are not just relevant to industrialised countries however. Developing countries have their own particular problems which, due to lower general levels of income per capita and under employment, are far harder to deal with. In many developing countries the drive for capital accumulation, industrialisation, agricultural reform and growth has meant that questions of quality of working life have received relatively low priority. In addition, the main source of technological change in developing countries has been the transfer of existing technologies from the industrialised countries. The Director General's report to the ILO Conference in 1975 noted that: "dissatisfaction with conditions of work is itself aggravated by the fact that the technologies and forms of organisation, often imported, were devised in a different socio-technological setting, and are not always adapted to social and cultural environments in which they are actually applied".

It has been pointed out that the 'Green Revolution' in the agricultural sectors of some countries has not always had the positive economic effects that were hoped for it. Some of the qualitative aspects of agricultural work have also deteriorated as a result of changes. For example, surveys of areas using modern varieties of rice in some developing countries[(1)] have shown that it has led to a reduction in the volume of family labour and an increase in the volume of hired labour. This, along with other factors, such as economies of scale arising from the use of high yielding varieties, has led to the creation of landless agricultural labour force in an economy without a basis of stable employment to support them.

---

(1) See various papers in ILO:"Technology to Improve Working Conditions in Asia", 1979.

In the industrial sectors problems have also arisen with the importation of technology through 'turnkey' projects which when faced with very different cultures, infrastructure and environment do not operate technically in the same way as in industrialised countries. This may frequently lead to increased social problems at workplace level in the form of increased accidents and stress.

There are also examples frequently cited of 'dirty' industries or production processes which are no longer accepted in the industrialised countries because of their social cost, being transferred to developing countries. There is evidence, for example, of asbestos production and use,which is progressively being restricted in industrialised countries for health reasons,being transferred to developing countries.

Some developing country governments have emphasised that questions of quality and living and working environment cannot be allowed to interfere with development of objectives. In terms of the question of priorities this is clearly an understandable desire. However, in many areas the two objectives of quality and quantity need not conflict in the long term. Through developing a more educated labour force and higher quality jobs some developing countries have shown that technological change and improved working conditions can be compatible. The Director General of the ILO stated in 1975 that:
"in the more developed countries it is now being realised that an organic link exists between the volume and quality of employment. The creation of more and better jobs could be not only a social proposition but also an economic aim. I feel convinced that the social will has a dynamic force capable of affecting classical economic analyses. We saw this in the Sixties when we launched the World Employment Plan. Contrary to certain theories which were prevalent at the time, we suggested that employment development should become a major aim in development policies. The same boldness, born out of a similarly powerful social conviction, leads us today to put forward these two working hypotheses

which I shall now sum up and which are in line with the best traditions of this Organisation. First, it is essential not only from the immediate social point of view, but also from the point of view of subsequent economic progress, which is the foundation of social progress, to invest in the improvement of working conditions, irrespective of the degree of development of the country concerned. Secondly, this improvement, far from hampering the aim of employment development, strengthens it"(1). Domestic conditions and policies may be more important than a particular technology in influencing working conditions.

The relationship between technology and job quality

Many of the factors affecting the impact of technology on job quality are analogous to the factors affecting the level of employment. Technological change has conflicting effects on the quality of work in the same way that it has conflicting effects on the level of employment. The introduction of technological product and process innovations may well lead to the deskilling of some jobs and the upgrading of others compared to existing products and processes. In some cases, new technology has led to an improved physical working environment, whilst in other cases it has led to problems of increased isolation of the worker, increased supervision of work and the changed pace of work.

These conflicting effects reflect the fact that a particular technology does not determine a particular form of work organisation or a set of working conditions. The impact upon the working environment will be the result of a set of choices made

(1) ILO: International Labour Conference, 60th Session, 1975. Record of Proceedings, p.193.

during the planning and introduction of the new technology. Where these choices are made consciously it is the economic, technical or social objectives which the technology is used to achieve that determine its effects upon employment in general and working conditions in particular. If a rational assessment is made of the longer term economic and social choices presented by new technology, then certain positive opportunities for improving living standards and the quality of working life do exist. If, however, the driving force behind technological change is one of rationalisation, increasing measured productivity and short-term profit, then this may well lead to a general deterioration in the quality of work.

In talking of job quality and technology it is useful to draw a distinction between tasks and jobs. Any job is likely to be made up of a series of different tasks. Whilst the tasks may be directly related to a particular technology the jobs are socially determined. Whether all the boring and repetitive tasks are concentrated in one set of jobs and the interesting tasks in another set of jobs, or whether they are distributed across different jobs, is an organisational rather than a technological decision.

If the driving force behind technological change is rationalisation, then new technology based on microelectronics offers considerable scope for deskilling and standardising jobs which at present require a high level of skill and training. This reduces the dependence that employers have upon groups of skilled workers, for example skilled craftsmen in the printing industry. New technology can also be used to achieve greater management control over the type of work and pace of work of a formerly skilled craftsman. In turn, new technological elites are created upon whom employers depend and who can command, in the short term at least, high salaries in return for their skills. In the present case the new technology has produced a demand for computer specialists: systems analysts, programmers, and electronics engineers. A future wave of rationalisation and technical innovation may deskill and standardise these jobs. In fifteen years time the unemployed and redundant computer programmer may have replaced the unemployed steelworker or displaced typesetter in industrialised countries as the object of retraining programmes or early retirement.

The dangers of this pattern of development are considerable, not only for skilled workers in existing industries but also for society as a whole. New technology may result in societies becoming even more polarised than they are at present. On the one hand there may be a mass of lowly-skilled operators monitoring highly automated systems of production and competing for their jobs with the unemployed, and on the other hand a small technological elite.

These problems of deskilling are not just related to current technologies. A similar process was seen in the nineteenth century during periods of industrialisation. De Tocqueville wrote in 1835: "when a workman is increasingly and exclusively engaged in the fabrication of one thing, he ultimately does his work with singular dexterity: but at the same time he loses the general faculty of applying his mind to the direction of the work. He every day becomes more adroit and less industrious; so that it may be said of him that in proportion as the workman improves the man is degraded".[1] The same effect is true of some of the technological change taking place today.

---

(1) De Tocqueville : "Liberalism", 1835.

Alternatives do exist, however, to design computer systems which use the existing skills of the workforce and add to them computer-related skills associated with the new technology. This may mean less central management control than technological options which concentrate computer skills requirements in a few centralised technical jobs; but it is likely to result in a better end-product and better quality jobs. The cost savings may not be so dramatic but the end result will be better.

Some examples

In industrialised countries one of the activities where technological change has resulted in a general deskilling of craftsmen has been in use of computer numerically controlled (CNC) machine tools. A study by Senker[1] of the use of CNC machines in the British tool-making industry found that the skill required by craftsmen tended to be reduced. In most industrialised countries the operators of conventional machine tools have traditionally been highly rated within the hierarchy of manual jobs. The task is highly skilled and requires a long period of training. The tasks of the machinist include assisting with the planning of the production of a part, setting up the machine, and controlling the speed and operation of the machine according to varying local circumstances such as the quality of the metal. Whilst the job involves communicating with both management and the draughtsman and designer of a part, the machinist retains a high degree of freedom and control over his job.

---

(1) P. Senker et al: Technological Change, Structural Change and Manpower in the UK Toolmaking Industry, E.I.T.B., 1976.

The introduction of computer numerically controlled (CNC) machine tools can be seen as a process innovation which is generally substitutive in its effects on labour skills. The skills of the machinist are broken down into their logical components by the analyst and programmer and the computer is programmed to control the operation of the machine tool in a similar way to the machinist. The control of the machine tool is transferred from the operator to the systems specialist, who analyses his skills. The job of the machinist is changed into one of monitoring the computer controlled equipment.

Similar experiences have been found with other forms of computerised equipment. A case study of a British firm where electronic process control machinery was introduced found that: "probably the most striking change in work organisation is the substantial transfer of skill from the shop floor to the office. In particular, although shop floor operatives have always been classified as semi-skilled, the more experienced workers and the foreman previously played a major role in setting and adjusting machinery. Now it is more or less established that setting is carried out by process controllers"(1)

The result of these and other case studies, however, suggests that the impact of CNC upon working conditions and skill levels is not fixed or inevitable. To quote one study: "there is no effect of CNC use as such, ...it is inadequate to consider a production technology as given and observe effects on constraints which follow from it,...technical development interacts with organisation and manpower development"(2). The key variants

(1) B. Wilkinson:"On the Negotiation of the Technical and Social Organisation of Work: A Case Study of the Application Process Control Mechanisms", 1981.

(2) A. Sorge et al: "Microelectronics and Manpower in Manufacturing", 1983.

affecting the impact of the technology on the job content include:- plant and company size; batch size; type of cutting and machinery; national institutional structure; and socio-economic conditions.

Where CNC is introduced to provide increased flexibility and design sophistication in the product rather than increased productivity, a highly centralised form of work organisation may not be satisfactory. Different organisational options do exist with the introduction of CNC machines. Due to the reduction in cost of computing brought about by microelectronics, data processing facilities are now distributed to the level of the machine tool. This means that operating programmes can be edited and altered at the level of the individual machine by a system of manual data input. Under centralised systems of CNC machine tools, any editing of programmes would be carried out by a computer programmer from a data processing department. In practice, however, it is possible for the machine tool operators to carry out an editing function if trained in basic computer programming skills. Indeed, in cases of small batch production or relatively straightforward production requirements it may be possible for CNC machines to be programmed at the shop-floor level. For example, a comparison of the introduction of CNC equipment in Germany and Britain found that the work organisation differed quite substantially between the two countries, even with the same technology. The German structure of organisation and skills favoured more the maintenance of control over work planning at shop-floor level[(1)].

Such options may lead to increased skill requirements in the machinist's job by harnessing existing mechanical skills with new computer skills. They may also lead to a better end-product. In the words of one writer, "it is usually easier to train a production engineer into the skills of part programming than it is to instil into a computer programme a lifetime's experience of feeds and speeds"[(2)].

---

(1) A. Sorge, op.cit.

(2) D. Hearn: Shop Floor and Management Aspects of Machine Tools", 1978.

Similar choices exist in the introduction of new technology in office work. For example, in industrialised countries word processing systems are coming to be used more and more widely in secretarial work. The introduction of word processing systems affects the skill levels of secretarial work in two ways. Firstly, it can result in a change of work organization with a splitting of typing work and administrative work. Secondly, it changes the skills required by the copy typist.

The introduction of word processors is frequently done through the establishment of a separate word processing department which would receive the bulk of typing work within an organization. This allows machinery to be kept working more intensively than is the case with traditional secretarial work structures and so achieves the maximum use of the capital equipment. The changed work organization results in the 'deskilling' of the word processor operator compared to a traditional secretary, since the job becomes one of essentially typing and no longer contains more varied administrative roles. Contact between typists and authors is also reduced as normally material is fed through the supervisor of the word processing department, who would also deal with any queries.

This organisational structure as described is only one of a number for introducing a word processing system into an organization. An American survey[1] of the introduction of word processing systems has described four different structures. One is a centrally administered system within an organization where all correspondence secretaries are located at the word processing centre and all typing within the organization is sent there. An alternative is to have satellite centres with typists trained in specialist typing skills and housing both administrative and correspondence secretaries.

(1) John Brennan: Quoted in J.Burns: "The Automated Office", Datamation, April 1977.

A third structure would have a back-up centre as an overload system for traditional secretaries. A fourth structure is to have a decentralised system where word processing facilities are located in the normal departments and less division takes place between the work of administrative and correspondence secretaries. The less centralised the system the less polarisation of skills that takes place.

It is clear therefore that in the introduction of office technology, choices concerning work organization do exist. The choice of whether or not to set up a highly centralised word processing department responsible solely for correspondence typing, with independent departments containing their own administrative secretaries, is a social decision, not a technical one. An equally feasible organization is for word processors to be used on a shared basis so that the correspondence content of several secretaries' jobs could be reduced, allowing more time for administrative tasks.

Although taken from industrialised countries, the above examples can also apply equally to developing countries. Choices exist concerning the impact of technological change on working conditions. Education and training policies are however essential to ensure that technological change does not lead to the substitution of unskilled jobs for formerly skilled artisanal jobs. Two commentators have argued:- "... high-tech industry, especially the manufacturing processes located in offshore locations like Singapore, will always be intensive in the use of unskilled, especially unskilled female labour. In many products and processes, rapid technological change, short product life-cycles, small series and customised production make automation difficult and uneconomic. Unskilled labour is the most flexible factor of production, since it can be retrained and redeployed more easily and quickly than a new machine can be designed and manufactured. It can also be profitably employed in small-scale and fluctuating production. Where there is automation and computerisation, equipment must still be run by human hands, and frequently has a 'deskilling' effect i.e. manual, visual and decision-making skills become less important for production operators, whose learning curves have not lengthened with technological upgrading."(1)

(1) Quoted in Global Electronics Information Newsletter, No.47, October 1984.

Conclusions

The main conclusion of this section is that the impact of technology upon the quality of work largely depends upon the objectives for which it is introduced. If the main goal is rationalisation and increased central control over working practices, then there is a danger of increased polarisation and segmentation occurring in most workplaces. If wider social goals are also treated as priorities, then substantial opportunities exist for improving the quality of work through technological innovation. These two sets of social and technical objectives need not be in conflict with one another. The earlier they are both introduced into the process of technological change the greater the scope for achieving them both. Where inevitable conflicts do exist however, it is better that these are faced up to at an early stage and reconciled rather than being ignored, as they are likely to emerge at a later stage when technology is in use. The need for mechanisms in handling the points of conflict is returned to in the later section on agreements for negotiating technological change (see pages 270-299).

III. NEW TECHNOLOGY AND HEALTH AND SAFETY AT THE WORKPLACE

General considerations

Closely related to the impact of technology on the working environment is its impact on health and safety. The influence of the working environment upon the health of working people is the result of a wide range of factors acting in combination. These include technical factors such as the materials used, manufactured and produced in the workplace and the equipment and production methods used. It also includes the social and organisational environment, and many of the qualitative work aspects referred to in the previous section will have an impact upon the health of the workforce.

It is useful to distinguish between three types of health and safety issues. Firstly, there are cases of dangerous and unhealthy working environments leading to industrial accidents and easily identifiable industrial illnesses. The ILO has estimated that in industry alone 50 million serious accidents take place a year. In industrialised countries on average one worker in ten suffers an industrial accident resulting in a loss of work. In the EEC countries each year between 9,000 and 10,000 deaths occur due to accidents at work and nearly 6 million accidents take place in total. The incidence of accidents is probably much higher in developing countries, although difficult to calculate.

Secondly, there are less easily identifiable cases of industrial illnesses arising due to exposure to health hazards at work. These may take many years to appear in the individual and it may take much longer to prove the link between the illness and the work. For example, it took many years for conventional wisdom in industrialised countries to accept the links between dust and chest disease in mineworkers, or the links between working with carcinogenic substances such as asbestos and subsequent fatal diseases. In an ideal world developing countries should have the advantage of being able to learn from the experiences of workers in industrialised countries with regard to long-term hazards. In reality, however, experience suggests that many hazardous jobs are exported to developing countries because health protection standards are lower.

Thirdly, there are clear links between general improvements in the working environment and general standards of health. In particular in the last decade industrialised countries have come to consider much more closely the links between psychological aspects of work such as stress and boredom and physical illnesses.

Technology affects all these aspects of health and safety at work, but a particular technology does not have inevitable consequences upon health. For example, increased computerisation offers important opportunities for reducing health and safety problems by:- allowing the automation of jobs in dangerous or unhealthy environments, e.g. paint spraying; providing better monitoring of industrial processes and so reducing the risks of accidents; removing the need for repetitive and boring jobs through automation; providing better information on health and safety issues,available more easily through computerised data bases. However, computerisation also poses dangers to health such as:- increased robotisation leading to increased accident risk; increased use of visual display units leading to eyesight problems; deteriorating work quality leading to increased stress; increased shift work leading to health problems.

The likely impact of given technology on health will therefore reflect the goals it is designed to achieve and the way it is introduced. A British government report has stated: "In theory robotics could also have applications where the repetitive nature of a job offers the risk of boredom leading to the careless use of existing machinery. In practice health and safety criteria are not always the most significant factors in determining whether processes are automated though they may clearly lead to such investment decisions if manpower simply cannot be recruited".(1)

Some examples

The two leading edge technologies, microelectronics and biotechnology, have brought with them very different, but very important sets of health and safety questions. As seen, microelectronics has led to the expansion of computerisation throughout the working environment in industrialised countries. Visual display units (VDUs) have become the standard means of communication between people and computers and as a result their use has spread widely throughout working life: currently in the United States there are more than 10 million VDUs providing access to computer systems. It is estimated that by 1990 more than half the workforce in industrialised countries will use VDUs.

As VDU use expanded in industrialised countries in the 1970s, it was accompanied by a growing number of health problems experienced by users such as eye-strain, stress fatigue, headaches and skin inflammation. It has also been recognised that

---

(1) UK Department of Employment: "The Manpower Implications of Microelectronics Technology", 1979.

VDUs can cause problems by increasing isolation at work. The exact effects depend on a complex range of factors covering both the equipment and work area. With regard to the equipment relevant factors are: screen brightness; colour of display; character definition; size and spacing; 'flicker' rates; tube implosion/explosion; radiation; heat generation; noise; cabinet design; maintenance and keyboard design. With regard to the work areas, relevant factors are: lights and glare; paperwork; position of screen; keyboard and paperwork; space and overcrowding; posture. Other important ergonomic factors are the opportunity for regular breaks away from the equipment so as to allow human contact and rest. Without this, the operator of a VDU can spend a whole working life looking at and interacting with a machine rather than with other people. This can lead to very real social and psychological problems for white-collar workers in the same way that mechanisation has led to problems for other groups of workers.

Some of these problems have been overcome by better design of equipment and workplaces. In several countries collective agreements or national regulations have been introduced which specify the way in which VDUs are used so as to minimize health risks. In general, the requirements of a safe use of VDUs are that: neither natural nor artificial light should cause glare on the screen; the characters on the screen should be easily readable; noise from the equipment should be kept to a minimum; the design of keyboards, desks and chairs should conform to ergonomic standards so as to avoid fatigue; VDUs should be positioned so as to allow social contact, but avoid overcrowding; operators should be given regular eye tests; operators should be given regular breaks away from VDUs. Research in some countries has also been directed at producing more ergonomically satisfactory VDUs through changing flicker speeds or developing new forms of displays.

Many of these problems have been overcome in the design of modern equipment. However, in the words of one VDU expert, "standards are still necessary because there are plenty of old VDUs about and we still manage to make the same old mistakes, especially at the bottom end of the market"[1]. For developing countries the real danger is that the 'same old mistakes' will become the norm.

Conclusion

As with the impact of new technology on the quality of work, it is clear that its impact on health and safety at the workplace is both varied and capable of being influenced in advance. Part of the problem is to ensure that adequate research is carried out in time to examine the health implications of certain technologies. It is then important that effective standards are adopted and implemented. The earlier the health and safety implications are dealt with the more likely it is that good standards can be compatible with economic and technical goals.

---

(1) Tom Stewart - member of International Standards Organisation ergonomics technical committee addressing International Trade Union Conference on VDUs, Geneva, October 1984.

PART II

AGREEMENTS FOR NEGOTIATING TECHNOLOGICAL CHANGE

I. TECHNOLOGICAL CHOICES

Previous sections of this report have shown thatthe introduction of new technology can result in very substantial changes in both the level and pattern of employment on a global, national, regional and industrial basis. These in themselves reflect changes taking place at the level of the enterprise or organisation and indeed at the level of the individual workplace.

Manning levels, skill requirements, the working environment, health and safety, career prospects, job satisfaction, working time and pay levels are all features of working life which may be quite dramatically transformed by technological changes. Changes may in fact be at their most dramatic when new 'greenfield' enterprises are established incorporating state of the art technology and quite different work organisation structures from existing plants in the same sector, industry or area.

A central theme of earlier sections has been that the overall direction and impact of these changes is not predetermined by the technology. As seen in different social and economic environments, a particular technology may have very different effects. The impact upon the working environment will also be affected by the choices made by the 'actors' involved in introducing new technology. The 'actors' include those who are responsible for introducing change, normally management, and those who will have to work with the technology, the workforce and their trade unions. Conscious technological choices may be made to achieve certain organisational objectives at the expense of others. For example a particular technological option may be chosen on the basis of its cost saving or rationalising potential irrespective of the effect that this may have upon employment levels or the health of workers involved. However, frequently technological choices may be made unconsciously where alternative technological options are simply not known or considered when change is planned and implemented. For example in many enterprises, even in advanced industrial countries, when a new computer system is designed the systems analyst will never be asked to consider the impact of his design upon the jobs of the people who will have to work with that system. The possibility of meeting both social and economic objectives is therefore never raised.

For the 'actors'' involved in implementing and coping with changes the scope of choice may seem constrained by a range of features such as the economic position of the firm, time constraints, lack of expertise and organisational pressures. The task of policy-making must be to widen the scope of choices by lifting constraints and to make the 'actors' aware of alternative choices. It must then ensure that procedures are introduced which allow optimum choices to be made. This covers the range of economic and social policies which accompany change but it also covers the institutional arrangements by which change is introduced at a workplace level. This section considers the implications of technological change for industrial relations systems and some conclusions about best practice and model agreements.

II. CONFLICT OF INTEREST OR SHARED INTEREST?

A pluralistic view of change

The arguments described in earlier sections concerning the economic and social costs and benefits of technological change reflect to some extent different sociological, just as much as economic, views of the world. On the one extreme our societies are depicted as having a unity of interest where technological change is often depicted as being wholly desirable and bringing benefits to all. On the other extreme societies are interpreted solely in terms of class conflict in which technology is essentially a weapon of one group in society against another.

Depending upon where one is placed in society it is convenient to interpret events through an ideology in which everyone should agree with one's view of the world. Those who gain from technological changes in the short term are likely to adopt a unitary analysis in which their interests are perceived as being in everyone else's interests as well. This could be paraphrased as what's good for General Motors is not only good for the United States but for mankind as well. On the other hand those whose direct interests are threatened by change are likely to adopt a class conflict analysis in which potential benefits that may accrue to everyone arising from technological change are discounted.

In reality most Commonwealth countries are essentially pluralist societies in which, as has been seen in the short term, the adjustment process is likely to mean that technological change will result in costs and benefits being distributed unevenly between groups. This will mean that there may often be a conflict of interest between different groups. Over time generalised benefits will flow from harnessing technological innovation which surpass many of these short term conflicts. However, it has also been pointed out that the danger can exist of certain groups or regions remaining permanently disadvantaged.

The optimum position must be to ensure that there is a trade off between different costs and benefits so that short term conflict does not prevent long term benefits being achieved. Arriving at this optimum requires the existence of systems for representing the interests of different groups affected and the possibility of negotiation based upon equality of power. At the enterprise level it is just this trade off possibility that industrial relations systems are designed to offer.

Within some high technology producing and using industries the importance of ensuring high quality products and the importance of the workforce in this process have led to what have been called 'new personnel management' policies being introduced. Such policies have different emphases in different countries but often include such questions as communication of management goals to the workforce, the establishment of 'quality circles' etc. Such measures may well be desirable in their own right but they are not necessarily an alternative to effective industrial relations procedures. Effective industrial relations procedures need to allow workforce representation to be autonomous from management if it is genuinely to represent their interests. This representation has to be a 'bottom upwards' process of personnel management rather than a 'top downwards' one. Moreover much of the agenda and orientation of the 'quality circle' approach is to involve the workforce in the achievement of management goals rather than to reconcile these with the independent objectives and interests of the workforce.

Different interests within an organisation

The most obvious groups with defined sets of interests likely to be affected by technological change are management on the one hand and the workforce and their trade unions on the other. For many countries, particularly in developing countries, these interests will be closely influenced in practice by the involvement of public authorities and governments in both industrial and labour policy.

At the level of the organisation, other and more complex sub-divisions of interest may also take place. Organisational research suggests that the firm itself, within industrialised countries at least, is a highly pluralist organisation. "The firm may be represented as a series of large horizontally divided groups, divided by the nature of task, routinisation, generality of skill or knowledge, responsibilities and spheres of authority. It is divided vertically by the degree to which its market and status reference groups lie within or outside the firm. This segmentalised labour market constitutes a series of areas within which any given technological innovation has a different impact and presents differing opportunities or grievances. The shape of the resulting production function may, in the short run at least, result from the nature of the structure and the process of the negotiations within each of these areas as upon the existence of an overriding technological imperative"[(1)]. If this view

(1) J. Child and R. Loveridge (University of Aston): "Capital Formation and Job Generation within the Firm in the UK - a review of the literature and suggested lines of research" - Paper delivered to First EEC Symposium in Social Sciences, September 1981.

is correct then arguments over management prerogative have little practical relevance and trade union concern over workforce interests is clearly a legitimate issue to be raised in the change process.

One potentially useful generalisation is that management is primarily responsible 'upwards' within a firm through management hierarchy whereas trade unions are responsible 'downwards' to their membership. These two main actors can therefore be attributed different sets of generalised objectives which they may seek to maximise in the process of change.

Objectives of management

The organisational objectives which management will be seeking to achieve will typically include:- profit maximisation or optimisation, reduced costs, increased productivity, a reduced labour force, reduced waste, net budget targets, new product development. These will vary to some extent between product and process applications.

A survey of microelectronics use in British industry(1) for example found that advantages perceived by management arising from microelectronics use in products included:- better product performance (considered very important by 70 per cent of respondents), flexibility in new product development (66 per cent), more consistent quality product (54 per cent), lower production costs (47 per cent), greater customer appeal (42 per cent), higher sales volumes (31 per cent), and higher profit margins (23 per cent). Advantages perceived by management from using

(1) Policy Studies Institute : "Microelectronics in British Industry: The Pattern of Change", London, March 1984.

microelectronics in processes included better control of the production process (rated very important by 75 per cent), a more consistent, better quality product (74 per cent), more efficient use of labour (66 per cent), capital equipment (48 per cent), materials (45 per cent) and energy (35 per cent), and also lower costs of production (54 per cent), greater speed of output (49 per cent) and better working conditions (20 per cent). It would seem reasonable that these perceived advantages would correspond broadly to desired organisational objectives of management.

Objectives of trade unions

Trade unions would be expected to regard a separate set of objectives as priorities. For example, the British Trades Union Congress's checklist for negotiators covering new technology agreements(1) sets out besides a series of procedural objectives a list of substantive objectives concerning new technology. These recommend that union negotiators should:- press for increased production from new technology rather than job cuts; seek guarantees on job security; if necessary negotiate voluntary redundancy/enhanced redundancy pay; agree retraining schemes; seek reduced working hours; reward new skills; distribute the benefits of new technology across the workforce; ensure no machine monitoring of workers; monitor Visual Display Unit health hazards. The overall objective is therefore to use new technology to improve working conditions in the field of skills, hours, income, health and safety, training, job satisfaction and job security.

Most of these issues are closely affected by other factors apart from technological change. For example, as seen in the section on "The Impact of Technological Change on Employment", the question of job security and new technology is closely bound up with market and macroeconomic developments. For trade unions, new technology does have the importance of raising a whole set of issues related to working life at the same time in a way that few other changes do. When new technology is being discussed, so are most aspects of the working environment.

---

(1) Trades Union Congress: Employment and Technology, London, September 1979.

The reconciliation of objectives

Although trade union and management objectives towards new technology are clearly different from each other, they need not always be in direct conflict. Whether they are or not depends upon the possibilities offered by various technological choices. As seen from earlier sections in this report technological and organisational options exist whereby improvements in qualitative aspects of work need not necessarily conflict with meeting management goals such as lower costs or higher productivity. For example most computer manufacturers sell terminals with Visual Display Units which have separate keyboards from screens, and adjustable brilliance controls and printers with noise covers. These fairly basic features of good ergonomic design were not available on VDUs sold ten years ago. Pressures from VDU operators in Western Europe, largely channelled through their trade unions, forced computer manufacturers to respond through changes in product design involving little extra cost. For users there are both economic and social gains.

In some cases, however, high costs may be imposed either in lower productivity on the one hand, or in greater health hazards on the other, by particular technological options. For example, societies in Western Europe have now deemed that the health hazards imposed upon workers through working with asbestos outweigh the economic benefits accruing to the companies manufacturing and using asbestos. This had led to the public regulation of asbestos use and manufacture. This was not brought about however by a sudden impulse of social responsibility by legislators, but by constant pressure by trade unions over the last two decades since the health hazards of working with asbestos have become evident.

Conflicts are bound to arise therefore where the introduction of new technology does not allow the twin goals of improving the working environment and maximising cost reduction to be achieved at the same time. The conflict may be similar to one that arises between firms and consumers over product quality. If one aspect of the firm's output is regarded as the quality of the jobs it offers to its workers and the workers in this case are the consumers of that output, then the analogy may be fairly close. The goal in the long term should be to aim for improved quality of product and not just cost reductions, in the field of working conditions just as much as in the field of the end product. In the words of one writer: "Informed customer participation in product development is quite commonplace nowadays in high technology industries, and some transfer of those constructive supplier-customer attitudes to the realm of management-worker negotiations over changes in working conditions does not seem too much to ask for."(1)

One problem with new technology is that it may obscure the basic choices which are available to workers in terms of cost/benefit options and obscure the areas where real conflicts of interest may arise. This problem is analogous to the problem of product novelty in the consumer field, where a consumer may not be aware of the problems and advantages of a new technically complex product before buying it.

It is desirable that in handling technological change, mechanisms are developed whereby the conflicts involved in technological change are made explicit rather than remaining implicit and which allow compromises between different interests to be reached.

---

(1) P.A. David: "Microelectronics and the Macroeconomic Outlook", Stanford University Discussion Papers, 1982.

It is in the long term interest of both management and the workforce to have procedures which enable conflicts to be resolved on the basis of equality of power. One writer has summed up the issue in saying that: "The introduction of new technology may, on the one hand, present management with the opportunity to break down worker organisation, yet the very resistance that this induces may limit management's ability to introduce best practice techniques"(1).

The successful introduction of new technology ultimately depends upon the people operating the systems. If individuals feel aggrieved or resentful in a changed work environment they are unlikely to be working efficiently and may well frustrate and hinder the attainment of management objectives. The effort expended in solving potential problems and reconciling conflicts of interest before technological change is implemented is a worthwhile investment for management. Long term gains will outweigh the short term expediency of acting unilaterally.

When faced with a grievance at the workplace an individual may have two options for setting right the problem. These options have been described by some writers as the 'exit' and the 'voice' options. The 'exit' option would lead an individual to quit the firm and try to find an alternative job. This is clearly not a viable option in many circumstances. The 'voice' option would lead the individual to voice the grievance to management. By acting as a collective voice, trade unions can protect the individual from victimisation and institutionalise the 'voice' option of grievance handling. It is not surprising therefore

---

(1) J. Rubery: "Structural labour markets, worker organisation and low pay", Cambridge Journal of Economics, 1978, No. 2.

that turnover rates in unionised firms tend to be much lower than in a non-unionised environment faced with an otherwise similar labour market environment. A study by Freeman and Medoff(1) on the impact of unionisation in the United States found that turnover rates were 30 to 65 per cent lower in unionised compared to non-union plants. Largely as a result of this they found that productivity was higher in unionised plants than non-union plants. In a union environment it was also found that the joint regulation of rules made management more professional and less arbitrary in its personnel policy, which also led to economic gains. Overall they concluded that the welfare gains to the American economy as a whole arising from the collective 'voice' actions of trade unions outweighed the welfare losses arising from any monopoly behaviour in the labour market leading to higher wages at the expense of employment.

There exists therefore considerable scope for developing institutional structures for handling technological change through negotiation between management and trade unions which are to the advantage of both parties. It is significant that this is reflected in the attitudes of both management and trade unions in those areas where such procedures have already been implemented.

In the UK the National Economic Development Council carried out in 1983 a survey of firms in the electronics sector to examine the degree to which they provided information and consulted their workforces on the introduction of new technology(2).

---

(1) R. Freeman and J. Medoff:"What do Unions do?", New York, 1984.
(2) NEDC: "The Introduction of New Technology", London, 1983.

They found that of the firms who involved their employees in the process, all recorded improved industrial relations as a result of consultation. The specific benefits attributed to consultative arrangements by management included :-

- "increased commitment through involvement"
- "greater understanding of commercial and technical decisions by those on the shopfloor"
- "better understanding by managers of the issues that arise in the process of rapid change"
- "reductions in the amount of time involved in introducing new techniques"
- "increased readiness to accept redeployment"
- "improvements to the design of the product".

None of the managers attributed any damage to the firms' competitive performance as a result of their consultative procedures.

The specific benefits attributed to consultative arrangements by trade unions included :-

- "extension of negotiating rights to influence the process of introducing change, especially advance consultation with the company before it makes final decisions on system introduction and the possibility of monitoring its extension"
- "the introduction of change on an agreed planned basis"
- "increase in pay for new skills"
- "to stop or slow job loss, and especially to prevent redundancies"
- "to protect and improve working conditions, especially health and safety, and skill levels"

- "improved productivity".

Where dissatisfaction was expressed on the part of union respresentatives it mainly concerned the perception of management commitment to the agreement.

Similarly, a survey of case studies of the introduction of new technology in Western Europe carried out for the European Commission(1) found that in 'best practice' examples of the use and provision of information to trade unions, considerable advantages were perceived by management from the process. For example in a case study of a Swedish dairy where trade unions had been involved from the design stage in the investment in a 'greenfield site', the manager, although originally sceptical, subsequently admitted to researchers that the interventions by the worker representatives had important and valuable consequences for the design of the new dairy, the new work organisation and the transition to the new site. The technical staff were even more enthusiastic about the advantages which arose from the early and extensive involvement of worker representatives.

III. PRACTICAL EXPERIENCES

Strategies adopted

The preceding sections have sought to show that a 'best practice' approach to the introduction of new technology at workplace level brings with it substantial economic and social advantages. In reality strategies adopted over recent years have differed substantially from such an approach.

(1) Hugo Levie et al. : "Workers and New Technology; Disclosure and Use of Company Information", DG V EC, 1984.

Managements, rather than seeking to introduce change on the basis of consensus, have in many circumstances sought to manage by concealment or by the use of fear to get employee acceptance of change. There are still many examples of work-forces finding out about technological change for the first time when machinery is delivered to workplaces. Change is often offered on a take it or leave it basis whereby the fear of unemployment is used to coerce workers to accept change and where cost cutting and rationalisation are the sole objectives of change. In industrialised countries this management approach to change has undoubtedly been reinforced by the growth in unemployment and the current fear of redundancy. In many developing countries a unilateral approach to change may well be the norm. As is argued later in this section there may be particular problems in firms in the Export Processing Zones of certain countries where different labour standards apply from the national norm.

On the trade union side responses may vary quite widely as well. Broadly, four different approaches have been adopted: outright opposition to change; enthusiastic acceptance of change; conditional acceptance 'after the fact'; and attempts to influence change 'before the fact'.

The response of outright opposition to change has been one adopted by some organisations of working people where they have perceived that their interests are likely to be permanently damaged as a result of changes. In societies which offer little in terms of compensation to groups affected, such a reaction may be understandable in terms of self interest. Groups of workers may be expected to pay the full cost of changes for which society as a whole benefits. As pointed out in the section on the "Impact of Technological Change on Employment", Ricardo, writing on the effect of industrialisation in the early 19th century on industrial workers in Britain, commented that their opposition to change was "conformable to the correct principles of political economy"

In some developing countries the debate is still raging over the desirability or otherwise of introducing computer technology as a process innovation in services such as banking. In India, for example, a furious dispute has taken place between different banking unions, notably the National Organisation of Bank Workers and the All Indian Bank Employees Association, over the latters' agreeing to the computerisation proposals put forward by the Indian Bankers Association.

However, the strategy of outright opposition to technological change is unlikely to succeed in protecting jobs in the medium or long term. In the United States the typographers' union in the newspaper industry, the ITU, resisted the introduction of computerised type-setting in the late 1960s and early 1970s. This was due to the loss of employment opportunity and status that computerisation threatened for its highly skilled members. Ultimately, however, the union found that the bargaining position of its members was undermined by new technology, as disastrous strikes at the Washington Post and New York Times showed.

Even if total resistance to change was a feasible strategy, it would normally mean that incomes in general would remain lower than would otherwise be the case and so not be regarded as desirable. Few unions in industrialised countries are advocating outright opposition to technological change, and surveys suggest that union resistance, although varying widely between countries, is not a major fact on restricting change in practice. One comparative study of the introduction of microelectronics in industry in Britain, Germany and France found that "opposition from the shopfloor or trade unions has been a major difficulty for 16 per cent of the user establishments in the samples in France and 14 per cent in Germany, but for only 7 per cent in Britain. In Germany it is a problem experienced mainly in the longest establishments and in the mechanical engineering industry; in Britain most often in the printing industry".(1)

---

(1) Policy Studies Institute: "Microelectronics in Industry", 1985.

The other extreme union approach to change can be called 'enthusiastic acceptance'. Some unions have undoubtedly enthusiastically accepted the introduction of new technology as a way of increasing the competitiveness of their industry and hopefully preventing jobs going abroad or attracting new jobs. In those developing countries where growth has been focused on the export sector,trade unions have often actively supported the rapid introduction of product and process innovation, coupled with the expansion of training to raise skill levels. In Singapore,for example,the trade union movement has acted as a pressure on management to innovate as quickly as possible and raise skill levels in line with government policy. In the Republic of Ireland, which has also faced the problem of how best to achieve industrialisation from a predominantly rural base,the Irish Transport and General Workers Union has actively encouraged the introduction of new technology in firms.

Clearly such a strategy from a national trade union reflects the development strategy for the country as a whole. As was clear from earlier sections in this report however, whilst such an approach may be possible for an individual country or industry,it cannot be applicable to all. Indeed against the current background of virtually no overall growth in jobs, gains in one country tend to be at the expense of those elsewhere.

The third union approach to change,and probably the one which is the norm in most industrialised countries,could be called conditional acceptance of new technology 'after the fact' of its introduction. For example the Canadian National Union of Provincial Government Employees is quoted in a government report as saying "Our union is not naive enough to think that it can stop the revolution, nor do we want to. To the contrary, we want to be part of it"(1). Unions have sought to extract from management the best safeguards and best terms and conditions for their members that are feasible. The exact terms of agreements on technology have varied according to the

(1) Labour Canada:"In the Chips: opportunities, people, partnerships", 1982.

relative strengths of management and unions and the tools available to them through legislation or other means. Typical issues covered have been: the avoidance of redundancies and the handling of job displacement through natural wastage and retraining; income guarantees for displaced workers; the changes in pay systems and demarcation rules to cope with change; reduced working hours; and health and safety questions.

In the Federal Republic of Germany, for example, agreements at national level have been concluded across all major sectors affected by the introduction of new technology. In general, these have been defensive in nature. They have sought to protect workers from the negative effects of rationalisation and technological change, in particular against redundancy and downgrading. At work council level, trade unions have sought to use legal rights to information, consultation and regulation to influence new technology before it is introduced. Other rights which are relevant to the introduction of new technology are given in the health and safety legislation.

In the UK attempts to extend joint regulation of new technology have focused on the extension of collective bargaining through the conclusion of new technology agreements (NTAs). More than one hundred agreements have been surveyed, the majority of them concluded at company level.

However, for manual workers at least, the NTA represents the exception rather than the normal means by which the introduction of new technology is regulated. For white collar workers the NTA has been an important means for seeking regulation, in part because many of these groups are currently being affected directly by new technology for the first time.

It should be pointed out that whilst the bulk of NTAs concluded in Britain have been of an essentially defensive nature, they have been concluded over a short period and in a time of decreasing employment and falling production.

Similarly, in Australia the Australian Council of Trade Unions have recognised that in practice much technology is handled 'after the fact' by trade unions. In their 1983 Congress statement on technological change policy, the ACTU said "The failure of Governments and employers over a period of years, to give other than lip service to the need for planning the introduction of beneficial new technology, or for the social consequences that flow, particularly in the current economic circumstances, can only be interpreted as a rejection of the trade union movement's appeal for, and willingness to participate in, the planned introduction of new technology".

Whilst such approaches are necessary and in many cases valuable, unions have recognised that they still amount to defensive and reactive responses to changes proposed by management. This has led unions in some cases to try and develop the fourth strategy referred to earlier, namely to attempt to influence technological change 'before the fact' of its introduction.

For example, achieving effective technical control against the background of computer technology is not just a question of laying down procedures or regulations for handling machinery or the computer hardware. It requires an influence over the design of the systems of which individual jobs and individual pieces of equipment form a part. For trade unions this process of influencing systems design means getting access to management at a much earlier stage, as soon as, or indeed before, change is contemplated. It means harnessing the knowledge and demands of work groups concerning the production process and harnessing outside expertise to demystify the technology. It requires a greater emphasis on union education and research programmes as well as obtaining rights to information from management. But at the end of the day it also means maintaining the unions' bargaining power and right to veto changes. Such 'before the fact' strategies are inevitably more difficult and deal with issues that are less tangible than straightforward responses to change. But they offer the best real hope of influencing change.

Procedures in industrialised countries

The 'best practice' approach is therefore one in which management and union jointly agree and decide upon technological change at the planning stage and before the change is introduced. The actual procedures for ensuring that this occurs are likely to vary according to the industrial relations practices of a country.

The Table below summarises the way in which technological change is regulated at the workplace in some industrialised countries. As can be seen, in some countries legislation has laid down basic trade union rights in coping with change, such as the work environment and codetermination laws in Sweden. Elsewhere custom and practice or general framework agreements have laid down rights, such as in Norway and Denmark. In some sectors, including printing, sectoral agreements are the norm, whilst in others company level or local agreements covering technology have become increasingly widespread (e.g. FRG and UK).

SUMMARY OF PROCEDURES OF JOINT REGULATION OF TECHNOLOGICAL CHANGE IN SELECTED INDUSTRIALISED COUNTRIES

COUNTRY	UNIONISATION RATE %	LAWS USED	COLLECTIVE AGREEMENTS: NATIONAL FRAMEWORK AGREEMENTS	COLLECTIVE AGREEMENTS: SECTORAL LEVEL	COLLECTIVE AGREEMENTS: COMPANY OR PLANT LEVEL
FRG	40	1)WORKS CONSTITUTION ACT 1972 2)WORKS SAFETY ACT 1975 +REGULATION ON WORK WITH VDUs 1981	NONE	JOB PROTECTION AGREEMENTS IN METALWORKING, TEXTILES, FOOTWEAR, LEATHER, PAPER PROCESSING, PRINTING	UPWARDS OF ONE HUNDRED AGREEMENTS CONCLUDED
GREAT BRITAIN	50	HEALTH AND SAFETY AT WORK ACT 1975	NONE	PARTS OF PUBLIC SECTOR	UPWARDS OF ONE HUNDRED AGREEMENTS
NORWAY	45	WORKING ENVIRONMENT ACT 1977 + REGULATION ON WORK WITH VDUs 1982	1975 AGREEMENT ON COMPUTER BASED SYSTEMS NAF-LO	BANKING	MOST OF INDUSTRY AND SERVICES COVERED BY LOCAL AGREEMENTS
DENMARK	70		1981 AGREEMENT FOR PRIVATE SECTOR BETWEEN LO AND DA	BANKING/PUBLIC SECTOR	
SWEDEN	75	1)WORKING ENVIRONMENT ACT 1978 + REGULATION ON WORK WITH VUDs 1981 2)CODETERMINATION ACT 1977	WORK ENVIRONMENT AGREEMENT SAF-LO-PTK 1976	TECHNOLOGY AGREEMENT IN THE PRINTING SECTOR, CODETERMINATION AGREEMENTS IN CENTRAL GOVERNMENT, LOCAL GOVERNMENT, PRIVATE SECTOR	USE OF LEGISLATIVE RIGHTS
ITALY	45	1)STATUTE OF WORKERS RIGHTS 1970 2)HEALTH AND SAFETY ACT 1978	NONE	CLAUSES INCLUDED IN SECTORAL AGREEMENTS ON METALWORKING	CLAUSES INCLUDED IN SEVERAL COMPANY AGREEMENTS EG FIAT, OLIVETTI, ALFA ROMEO
BELGIUM	75		1983 COLLECTIVE AGREEMENT ON NEW TECHNOLOGY	PRINTING	LOCAL AGREEMENTS IMPLEMENTING NATIONAL AGREEMENT
UNITED STATES	20		NONE	TECHNICAL CHANGE CLAUSES IN GENERAL AGREEMENTS	
AUSTRALIA	45	UNFAIR DISMISSAL LEGISLATION	NONE	TELECOMMUNICATIONS	AGREEMENTS IN PARTS OF PRINTING & PUBLIC SECTOR
CANADA	30	RECOMMENDATIONS FOR LEGAL RIGHTS	NONE	LIMITED CLAUSES IN EXISTING AGREEMENTS	
JAPAN	25		"	TELECOMMUNICATIONS	PLANT COMMITTEES
OTHER COUNTRIES		HEALTH & SAFETY LEGISLATION (EG FRANCE) CO-DETERMINATION LEGISLATION (EG AUSTRIA)	NONE	PRINTING SECTOR IN THE NETHERLANDS, AUSTRIA, GREECE	

In Canada technological change has led a Government 'task-force' to recommend substantial changes in labour legislation. They have argued that: "The legislative scheme which we envisage would require all employers of 50 or more employees to engage in ongoing discussion and consultation with employees or their representatives, in anticipation of technological change."(1) The task-force went on to recommend the establishment of Joint Technology Committees between manangement and unions and to introduce arbitration in cases of disputes over the introduction of new technology.

In Australia the Government have published for discussion a national technology strategy which proposes a range of actions in the area of industrial relations including:- the establishment of principles of good management practice; the establishment of minimum standards in federal awards regarding unfair dismissal; consultation on the introduction of new technology; and the introduction of guidelines covering union consultation on the introduction of technological change. The ACTU has demanded that in addition, the Government should establish a national office of technology assessment.

It is significant that in the United States in the 1970's, unlike the 1960's, there had been relatively little concern at the impact of new technology on workplace relations in general and employment in particular. Concern was also less in Japan. In part, this can be explained by the fact that this period was one of relatively rapid employment

---

(1) Labour Canada:"In the Chips" : Opportunities, people, partnerships", 1982.

growth in each country. Both Japan and the U.S. gained from some of the shifts in the pattern of world production and employment that were taking place as a result of technological change and, against a background of relatively rapid growth, the traditional areas of highly organised labour were less seriously affected by job loss due to new technology. The less articulate groups on the periphery of the labour market in both countries were in a less favourable situation.

There is however, increasing activity in the field of negotiations over new technology in both the United States and Japan. In the United States a survey of technological change clauses in collective bargaining agreements[1] has shown that such clauses had increased modestly in number during the 1970's, with a more marked increase in the non-manufacturing sector. The clauses cover a wide variety of subjects but most extensively workforce reductions, then retraining and wage security. The most common procedural issue covered was the advance notice of technological change, accompanied by provisions for consultation or negotiation.

In Japan, the trade unions have begun to raise the question of how to expand trade union influence in the introduction of new technology. In July 1982, one of the trade union national centres (SOHYO) published a report on trade unions and technological renovation which argued that they should "enlarge the sphere of union's regulatory influence, so as to be able to cover the area of production and technology management and cope successfully with technological renovation". The report went

---

(1) Ken Murphy:"Technological change clauses in collective bargaining agreements", AFL-CIO, Washington, August 1981.

on to argue that "if enterprise unions try to enlarge their influence individually without organising themselves, they are certain to be retaliated by a heavy market pressure resulting from inter-enterprise competition".[1]

The relevance for developing countries

The industrial relations background in industrialised countries covers a wide range of situations. Unionisation rates vary from 70-80 per cent of the labour force in some Scandinavian countries down to 20-30 per cent in the United States, Japan and France, with countries such as Australia, Britain, Germany and Italy falling mid-way in the range. Nevertheless, the establishment of joint procedures for handling technological change has become more and more a common feature of the differing industrial relation systems.

The situation in developing countries is much more variable, reflecting very different political and economic structures. Partly due to the high proportion of agricultural employment and under-employment in the labour force, the unionisation rates tend to be low when measured at national level. However, the overall low unionisation rates obscure pockets of high and effective organisation in certain economic sectors and geographic areas. For example in a country such as India, although the national unions claim a total membership of less than 8 million compared to a total labour force of some 250 million, the estimated unionisation rate in the economic sectors subject to unionisation is around 30 per cent. The pattern of unionisation in high technology sectors varies considerably between countries but probably reflects the general national norm for other industrial sectors.

---

(1) SOHYO : "Trade Unions and Technological Renovation", Report No.1 - July 1982.

Even where trade unions have less organised strength than in industrialised countries they may have political influence due to close links with political parties. For example in Singapore the National Trades Union Congress (NTUC) has very close relations with the major political party PAP. And besides organising one third of the labour force, the NTUC also runs a wide range of corporations including supermarkets, insurance, child care centres and taxis. It is significant that the NTUC in Singapore works closely with the government in pursuing the development objective of raising skill and wage levels so as to influence the pattern of industrial development.

The importance of the state in tripartite procedures, as opposed to bipartite ones, can pose difficulties for trade unions in developing countries as well as advantages. In developing countries as a whole, the ability of trade unions to organise, their ability to take industrial action and the scope of negotiable issues is more closely restricted by the state than in industrialised countries. A crucial factor affecting the ability of trade unions to regulate new technology in some countries is therefore whether governments see this as desirable. Changes in government policy and in some cases legislation may therefore be necessary in order to facilitate the way for the negotiation of technological change.

In some countries it is also the case that the ability to establish independent trade unions and their ability to operate normally is restricted, either by government action or by the activities of employers. In these circumstances it is understandable that the priority objective has been to establish free trade unions and basic trade union rights, rather than immediately to extend the negotiating remit into areas such as new technology.

The ratification and application of ILO conventions gives one benchmark by which to compare the application of what have come to be known as 'good labour standards' The Table below shows the extent to which basic conventions concerning trade union rights and labour conditions have been ratified in two groups of countries, one of industrialised countries (EEC) and the other of developing countries (ASEAN).

Ratifications of ILO Conventions December 1983 in ASEAN and EEC Countries

	1	26/131	81	87	89	98	100	111	138	141	144	151
ASEAN												
Indonesia	-	-	-	-	-	x	x	-	-	-	-	-
Malaysia	-	-	x	x	-	x	-	-	-	-	-	-
Philippines	-	-	-	-	x	x	x	x	-	x	-	-
Singapore	-	-	x	x	-	x	-	-	-	-	-	-
Thailand	-	-	-	-	-	-	-	-	-	-	-	-
EEC												
Belgium	x	x	x	x	x	x	x	x	-	-	x	-
Denmark	-	-	x	x	-	x	x	x	-	x	x	x
Germany	-	x	x	x	-	x	x	x	x	x	x	-
Greece	x	-	x	x	x	x	x	-	-	-	x	-
France	x	x	x	x	x	x	x	x	-	-	x	-
Italy	x	x	x	x	x	x	x	x	x	x	x	-
Luxembourg	x	x	x	x	x'	x	x	-	x	-	-	-
Ireland	-	x	x	x	x'	x	x	-	x	-	x	-
United Kingdom	-	x	x	x	-	x	x	-	-	x	x	x
Netherlands	-	x	x	x	x'	-	x	x	x	x	x	-

Ratified Conventions

No. 1 Hours of Work
No. 26/131 Minimum wage-fixing Machinery
No. 81 Labour Inspection
No. 87 Freedom of Association and Right to Organize
No. 89 Prohibition on Night Work for Women
No. 98 Right to Organize and Collective Bargaining
No. 100 Equal Renumeration
No. 111 Discrimination (Employment and Occupation)
No. 138 Minimum Age
No. 141 Rural Workers' Organizations
No. 144 Tripartite Consultation
No. 151 Labour Relations (Public Service)

Source: ILO quoted in Background Paper for ICFTU Conference on the trade union role in ASEAN/EEC relations

An equally important point has been the extent to which ILO conventions are applied in practice in developing countries, even when they have been ratified. The application of ILO conventions within Export Processing Zones (EPZs) has been one area of particular concern. The ICFTU, for example, has argued that workers in EPZsin practice face particular difficulties in organising and operating[1]. As a result of these concerns the ILO since 1981 has been surveying the effect of the creation of EPZs in various parts of the world on the application of ratified conventions. Its conclusions have been summarised each year in its annual Report (see for example the 1984 report[2]). It has noted that in some countries (e.g. Pakistan) labour standards in EPZs have posed problems for the implementation of conventions. In others (e.g. Mauritius) EPZs have had lower labour standards, for example on holidays, overtime and night work for women, but this has mainly concerned conventions which have not been ratified by the countries concerned. In general, however, the ILO has noted that many of the countries possessing EPZs have not submitted information to them.

It is important to note that in some countries with export oriented industrialisation strategies the attitude of public authorities to trade union activities is changing. In Malaysia, for example, there was until 1983 a government ruling that workers in electronics sectors could not join the Electrical Industry Workers' Union (EIWU) on the grounds that it represented workers in a different industry. The Malaysian Trade Union Congress and the International Metal Workers' Federation lodged a complaint with the ILO in 1979 against this ruling. It was changed in 1983 and organising activity has been carried out by workers at several plants with the help of the EIWU. In April 1983 the EIWU won recognition at an ITT subsidiary's plant based in one of the

---

(1) International Confederation of Free Trade Unions (ICFTU): "New Technology and Womens' Employment",1983.

(2) ILO Report of the Committee of Experts on the Application of Conventions and Recommendations, 70th Session, 1984.

Malaysian EPZs. This followed a government ruling after the union had recruited 423 of the plant's 530 workers. Even where trade unions are organised they may have considerably greater difficulties in handling the issues thrown up by new technology than trade unions in industrialised countries. Strategies of trade unions in developing countries may therefore often reflect the 'outright rejection' or 'enthusiastic acceptance' strategies described earlier in this section. They may find it more difficult to effectively influence change in a way that is both socially and economically desirable. One of the key issues affecting both trade unions and developing countries in general is the importance of education and training of the workforce and trade union representatives to enable them to handle issues of technological change.

Despite the extra difficulties in developing countries concerning negotiating technological change, it is argued in this report that the approach of introducing change with agreement is the most desirable strategy in the long term. The previous sections of this report have shown that by acting as a collective voice, trade unions can have a positive impact on efficiency and productivity and the ultimate technological choice made at enterprise level. This is just as valid in developing countries when new technology is introduced as in industrialised countries. It is sometimes claimed that by raising wage costs in developing countries, trade unions would reduce comparative advantage vis-à-vis the industrialised world. However, in reality trade unions are only likely to have a significant impact on wage levels when they are working with market forces rather than against them. Indeed when new technology is introduced, this can allow the goal of higher incomes to be met through higher productivity rather than higher prices. It should also be pointed out that trade union strategies for higher incomes are only likely to succeed when they coincide with government development objectives, as seen for example in Singapore.

Finally it is worth emphasising the link between political and industrial democracy. Independent trade unions represent an important pillar of democratic, pluralist societies. Developing their capabilities and representativeness on issues such as technological change is an important factor in encouraging political democracy.

IV. A MODEL AGREEMENT

Despite differences in practical application therefore, the extension of negotiations on the introduction of new technology is regarded by this report as a desirable goal. The main features of 'best practice' approaches contained in agreements and legislation is summarised below[1]:

Procedurally, the agreements typically specify :

- the commitment of both management and trade unions to the introduction of new technology and the satisfactory management of change;
- the provision of information by management to the trade unions on the introduction of new technology, at an early stage, before decisions are taken and when final choices can be influenced. The information should allow for transparency with regard to the effects of changes and the choices to be made;
- the establishment of management/union bodies to discuss, monitor and negotiate change;
- the opportunity for the election and training of trade union representatives with specific responsibilities for monitoring the introduction of new technology, but with close links to the membership;
- the possibility of access by the union in a plant to outside expertise, in some cases paid for by, although independent from, management;
- the establishment of a procedure for monitoring and regulating the collection of personal data on individuals working in a plant and for regulating its use;
- the inclusion of a 'status quo' clause whereby the unions have the right to veto changes unless they are agreed.

---

(1) For a more extensive model agreement see that published by the International Federation of Commercial Clerical Professional and Technical Employees (FIET), Geneva, 1983.

In terms of the substantive issues regulated by these procedures, agreements typically specify that:

- there should be 'no redundancies' as a result of the introduction of new technology. In some cases, unions have even been able to ensure that there should be no reduction in the volume of employment;

- staff whose jobs are changed or eliminated due to technological change should be retrained and given jobs of comparable status in the same enterprise. Downgrading should be limited;

- for older workers, voluntary schemes of early retirement should be introduced and, in general, working time should be reduced to ease employment problems;

- the introduction of new technology should not be used to increase the pace of work, control and supervision or to reduce job contact or lead to a higher incidence of shift working;

- the health and safety aspect of working with computerised equipment and visual display units (VDUs) should be closely regulated; the design of the equipment and working place should conform to ergonomic standards; the amount of time spent working with VDUs should be limited; regular breaks away from the machine should be provided for; and regular medical check-ups made available;

- the personal information collected on employees should be strictly limited to that relevant to the activities of the company;

- the pay levels of displaced workers should be guaranteed; new grading levels should be introduced for those operating new equipment, but it should not be used to increase pay differentials.

These points might be taken to represent a code of good practice in introducing new technology. It is clear that the particular institutional form of agreement or approach needs to be adapted to national circumstances. In developing countries, particular attention needs to be given to establishing and developing free trade unions in the first place and then to developing training and education to equip the workforce and its representatives with the expertise to handle the issues raised by technological change.

CHAPTER IV

THE CHOICE OF INDUSTRIAL TECHNIQUES IN DEVELOPING COUNTRIES

James Pickett

David Livingstone Institute of
Overseas Development Studies,
University of Strathclyde,
Scotland.

May 1985

THE CHOICE OF INDUSTRIAL TECHNIQUES IN DEVELOPING COUNTRIES

Contents

THE CHOICE OF INDUSTRIAL TECHNIQUES IN DEVELOPING COUNTRIES

Introduction

A major purpose of this paper is to consider whether, other conditions being met, the range of extant industrial techniques is sufficiently large and sufficiently dense to make optimal choices possible.[1/] This raises questions about the operational meaning of optimality. It also raises questions as to why the most desirable techniques might not be chosen, and of policies that might improve choice. In considering these it is important to recognize that the range of choice is continuously changing under the influence of technical progress, so that it has to be asked if particular techniques now available might not too quickly become obsolete or suffer from other disadvantages.

The main body of the paper is in three parts. The first considers the meaning of optimality and the characteristics of techniques; the second explores the availability of alternatives, their appraisal and the consequences of choice; and the third discusses some aspects of technical progress and the policy implications of the first two sections. Before turning to these substantial issues it is as well to acknowledge that, for some, reasons for dwelling on the choice of industrial techniques may not be self-evident. Moreover it is not difficult, as things now are in many countries, to create a presumption that returns to investment in peasant agriculture are higher than in other sectors.[2/] Even, however, if this were well-founded and acted upon, attention would still have to be paid to industrial development. Effective policies toward the peasants would lead to income growth which would increasingly translate into a demand for industrial goods - some at least of which could be expected to be produced domestically. Again a decision to give priority to peasant agriculture would - in virtually all developing countries - have to recognize the already established urban populations with their particular interests and patterns of demand.

Given that industrial development will continue, the methods of production used will affect the quantity of investible funds available in other sectors of the economy. This is particularly so if - as is widely believed - decisions have an urban bias which makes the allocation of resources outside the modern sector something of a residual matter - without necessarily ensuring that urban decisions are themselves efficient. Indeed many developing country plants are characterized by under-utilization of capacity, uncompetitively high unit costs, and consequently a record of loss-making. Why developing country industry should be thus inefficient is not a question to command a single answer.
It may, however, be noted that part of the reason lies in the use of inappropriate techniques. More appropriate choice could consequently increase industrial efficiency and release investible funds for use in agriculture.

Close attention to the choice of technique could also help ease the employment problem. On the supply side this has its roots in unprecedentedly high rates of population and hence labour force growth. Taken in conjunction with poverty and the consequent low levels of savings, the rapid expansion in the number of workers can be translated into a (low) target cost per work place which would be consistent with substantial employment. For some the cost per job becomes a measure of the appropriateness of techniques. As will be seen this - on its own - is not satisfactory. Nor are more general prescriptions which make appropriate techniques either exclusively capital- or exclusively labour-intensive. To develop this argument would, however, quickly lead to the substantial discussion, so that it is now convenient to turn to this.

I. Optimality and the Characteristics of Techniques

(a) Some Theory and a Paradox

In conventional economic theory there is no great difficulty with the meaning and identification of an optimal technique. Consider what this theory has to say about the production, at a given level of output, of a well-specified product in a developing and a developed country location respectively. In the former it may be assumed that labour is relatively plentiful and capital relatively scarce, with the factor endowments being reversed in the developed country. The theory assumes that there are very many different ways in which the given good can be produced, and that factors are priced in keeping with their opportunity costs. It also assumes that the aim in both locations is to maximize profits. The optimal techniques will not, however, be the same in the two locations, since variations in capital-labour ratios are the standard response to variations in factor prices.

The choices of technique are illustrated in Figure 1. Reflecting relevant endowments, the factor price lines are

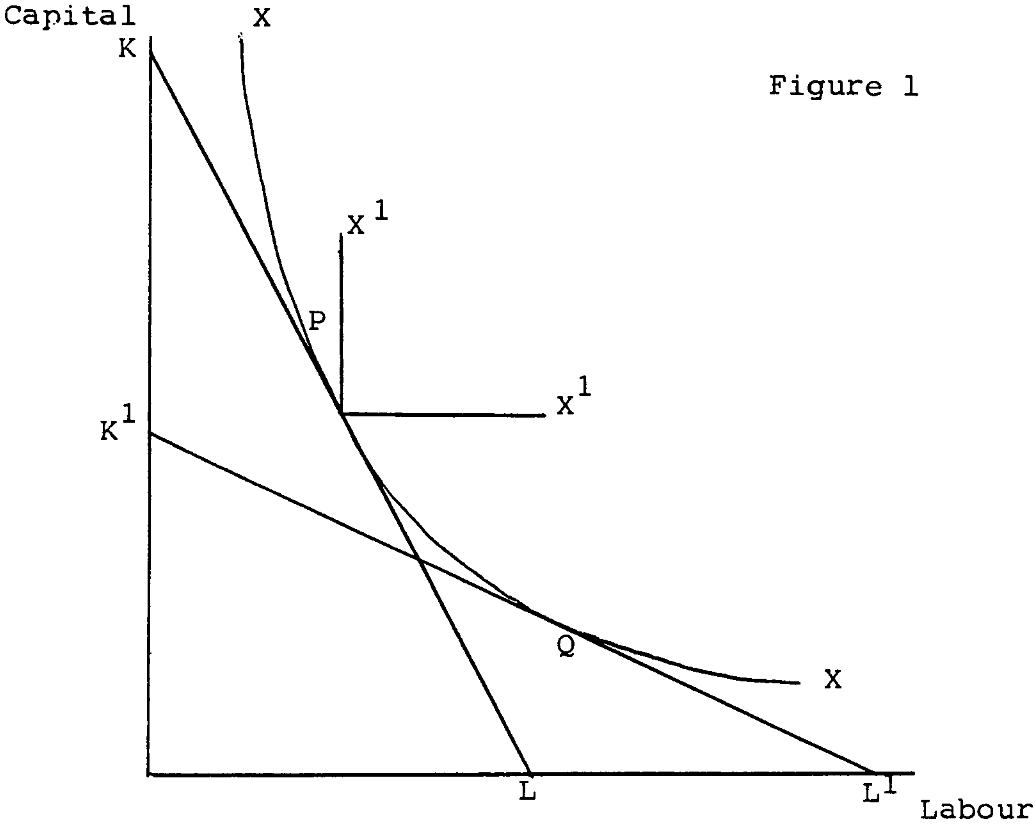


Figure 1: Optimal Techniques and Factor Endowments

KL (developed) and K^1L^1 (developing) respectively, so that, given the shape of the production isoquant XX, a factory located in a developed country would operate - as it were - at P and one in a developing country at Q. The points P and Q represent optimal techniques - i.e. least cost ones - defined by the condition that the marginal products of the two factors be proportionate to their prices.[3/]

If productive factors were internationally mobile the situation depicted in Figure 1 could not persist. Capital would move in one direction and labour in the other until relative factor prices were equalized and production characterized by a common capital-labour ratio.[4/] Mobility - particularly of labour - is, however, constrained. The presumption of different production techniques (capital-labour ratios) in different locations is, therefore, a reasonable one. 'Low'-wage countries should use labour-intensive and 'high'-wage countries capital-intensive methods of production. Yet the expected very wide spread of capital-labour ratios in any given industry is not generally to be observed as between developed and developing countries. Even in the latter the plant and machinery in use often seems more appropriate to factor proportions in rich than in poor countries. This is, of course, apparently paradoxical since it suggests that profits <u>and</u> employment are lower than they need be.

The failure of the theory to predict the behaviour of developing country decision takers could, of course, simply mean that there is something amiss with the theory. In this regard exception could be taken to the assumption of profit maximization, opportunity cost pricing and the plentiful availability of alternative techniques. If decision takers did not aim to minimize their production costs, other forces - including, for example, engineering pride, an aversion to 'troublesome' labour and national dignity - could come into play, particularly if markets were not competitive.[5/] The conditions that would be required for opportunity costs to be accurately registered in the market are not met in the second-best world of developing economies. In addition to other market imperfections, governments frequently act to cheapen capital in relation to its true opportunity cost and - in collusion with or under pressure from trade unions - to raise the price of labour. Consequently the price line K^1L^1 of Figure 1 has to be swivelled round in the direction of the developed country price line if it is to reflect observed prices. This done, a profit maximizing decision taker would choose a technique for a developing country that is much closer to that of the optimum choice in a developed country than it objectively should be. If there is little or no choice of techniques, the isoquant, XX, of Figure 1 is no longer appropriate. In the extreme it would be replaced by another isoquant, X^1PX^1, and the only choice in a developing country would be whether or not to use the one technique available.

These three explanations for the paradox would suggest different policy measures - increasing competition perhaps, getting the factor prices right and organizing a search for alternatives. Policies are discussed more fully below. In the meantime it is worth noting that all three constraints could be operating simultaneously. Screening by engineers could limit the effective choice to the capital-intensive reaches of the isoquant XX, with the selection from that limited range being made at distorted factor prices.

In the light of the foregoing, a little theory - even when it fails the supreme test of accurate prediction - seems to go a long way. Indeed it is convenient to explore one other feature of a theory that, in effect, assumes that only capital and labour vary across techniques. If this assumption were well-founded it would simplify methods of choosing among techniques - by justifying technical efficiency as a screening device.

(b) Technical Efficiency

Technical efficiency makes it possible to choose between techniques without reference to factor prices. If technique A uses less of both capital and labour than technique B, then - at any non-negative set of factor prices - it is clearly to be preferred to B. A should also be chosen if it uses less of one factor but no more of the other than B, and is said in these various circumstances to dominate A. Against this, if A uses more of one factor but less of the other than B it is no longer possible to choose between them by technical inspection. Economic calculation becomes necessary for choice. The techniques represented by the isoquant XX in Figure 1 comprise a technically efficient set among which choice is only possible on economic grounds. This does not, however, reduce the utility of the notion of technical efficiency since appeal to this would quickly rule out any techniques which would sit north and east of the isoquant.

Unfortunately the usefulness of the technical efficiency criteria is tightly tied to the assumption that techniques can be reduced to the relation between two homogeneous (or generally specified) factors. If different kinds of capital, different kinds of labour and varying quantities of raw materials have to be considered,the two-dimensional simplicity of Figure 1 disappears. The concept of technical efficiency can survive in a multi-dimensional world, but its operational effectiveness is much restricted;[6/] and in turning now to a more realistic consideration of what constitutes a technique than is to be found in Figure 1, it is necessary to stress that more changes with technique than the numbers of men and machines.

(c) The Meaning of an Appropriate Technique

For present purposes a technique may realistically be taken as the means and the methods to produce industrial goods. It consequently embraces a variety of factor inputs - including unskilled, semi-skilled, skilled, supervisory and managerial labour and capital tied up in machines, buildings, material stocks, work-in-progress and finished goods. Thus it is inadequate to describe techniques as being capital- and labour-intensive where capital refers only to machines and labour only to the unskilled. Techniques can also be skill-, management- or maintenance-intensive and to overlook this can result in seriously misleading results. A technique which employs much unskilled labour and relatively few machines can yet be more capital-intensive than a more mechanized alternative using fewer workers. The larger labour force could require higher expenditure on buildings, have a slower throughput and so a larger work-in-progress, and - because, for example, of more frequent breakages - need a larger stock of raw materials. Working capital, indeed, often represents one- to two-thirds of the total capital invested in a project. And, contrary to what is implicitly assumed in the theory discussed above, it does vary with the choice of technique.[7/]

In the light of these considerations it would be wrong to expect that any one industrial technique would be appropriate in all developing country locations. Even when scale of production and product characteristics are tightly specified, techniques appropriate to particular purposes in one country would be less so in another. Developing countries vary greatly in their availability of capital, various kinds of skills and general management competence. Consequently what is required is "a hierarchy of technologies appropriate to countries with a variety of scarcities and surpluses of different factors".[8/]

This variety notwithstanding, are there general standards that appropriate techniques drawn from this hierarchy should meet? Given the risks and uncertainties which surround industrial production this is not a question which should be approached dogmatically. Nevertheless it is useful to have an economically rigorous definition. Thus according to Sir Austin Robinson, an appropriate technique "is one which makes possible the production of a given good at a price not exceeding the current world price when:

(a) all factors of production are valued at prices that reflect their relative scarcities and opportunity costs and which will permit the full employment of all available supplies of all factors;

(b) the exchange rate is such that there is a balance of payments with this level of demand and activity, when allowance is made for a normal inflow or outflow of capital;

(c) the rate of interest or discount is consistent with a balance between savings and investment at this level of near full employment of all factors of production."

The crux of this definition is the use of opportunity cost, here stretched to include world prices and the exchange rate. Given the discount rate, a project life, and a full specification of alternative techniques, discounted cash flow analysis could capture the spirit of the definition by rank ordering economically-priced alternatives according to their net present values. That technique would be chosen that had the highest net present value - provided that this was positive when output was valued at the relevant world price. This way of applying the definition would - since NPV is a measure of economic surplus - correspond closely to the profit-maximizing assumption underlying Figure 1. The definition thus seems operational and consistent with the theory on which most economists are still brought up. In so far as the procedure just described could be used, the definition is operational and broadly provides the basis for the evaluation of techniques discussed below. Before turning to this, however, it is useful to register some caveats.

The definition differs from the partial equilibrium analysis underlying Figure 1 in that it has general equilibrium overtones. Granted an appropriate hierarchy of techniques, 'accurate' shadow pricing will deliver not merely the optimal technique in every line of production, but also full employment. This presumably is based on the usual neo-classical assumption that in any economy there will be some set of factor prices at which all markets including those for labour will clear.[9] Particularly in the light of the present levels of unemployment in the developed market economies this seems too heroic. Consequently the subsequent discussion in this paper does not include full employment as an objective. This is not, of course, to rule out a concern for fuller employment, so that the availability of employment-intensive techniques is still an important consideration. One characteristic of such techniques, so that more of them may be used, is that capital cost per job created should be less than, say, one-quarter of that associated with developed country techniques.[10/]

This choice of cut-off for the cost per work place is, of course, somewhat arbitrary. The underlying thought, however, is not. If massive un- and underemployment is to be avoided, developing countries have to find efficient techniques with capital-labour ratios much lower than those observed in the developed market economies. This may be illustrated by considering some aspects of the textile industry and some macro-economic features of the UK (a middle-range developed country) and Ethiopia (a particularly poor developing one). In present United Kingdom conditions, to set up an efficient factory of optimum size to produce grey cotton cloth would incur a capital cost of US $20 million and employ 240 persons, so that the capital-labour ratio would be US $83,333 per head. In Ethiopia the annual increment to the labour force may be put at 300,000. On the assumption of a savings rate of 10 per cent of the Ethiopian GDP, the absolute amount of investible funds available to Ethiopia may be put at US $9.3 million. This gives US $31 for each new entrant to the labour force. Against this, equipping new entrants to the standards of a British textile mill would require US $83,333 per head, so that if an attempt is made so to equip new workers the proportion of the 300,000 which could be employed in the modern sector would be miniscule. This proportion could rise, of course, if investible funds could be increased. In the present example, however, even if savings rose by a factor of 100 the point being made would remain.

This emphasis on the employment-intensive is important and possibly helps with another difficulty associated with full-blooded attempts to apply the above definition in empirical work - the need to use shadow prices. To estimate prices which accurately measured opportunity costs in all circumstances in which the appropriateness of techniques were to be judged is a tall order, particularly if investigation covers more than one country. Fortunately it may not be necessary to insist on shadow pricing. If there were techniques which seemed broadly efficient at market prices in developing countries,these would presumably be relatively sparing in their use of investible funds and relatively generous in their employment of unskilled labour. Given that shadow pricing would normally cheapen unskilled labour and make capital more expensive, appropriate 'market-price' techniques would be even more appropriate at true opportunity costs. Thus, the question is, do such techniques exist?

II. The Hierarchy, Appraisal and the Consequences of Choice[11/]

(a) The Production Process and the Range of Techniques

The first question that now arises is whether alternative techniques are available for the production of a closely-specified product (or product range) to some pre-determined level of output. Although some would deny that much choice exists,[12/] it is not difficult to create a contrary presumption.

Frequently the process of manufacture - of cotton cloth from raw cotton and of steel from iron ore, for example - begins with an agricultural or mineral raw material. At other times, however, the starting point is an intermediate product such as cotton and synthetic yarns and wool tops. Thus industrial processes can normally be divided into stages and the numbers of process techniques available will be a function of the number and 'independence' of stages and of the sub-techniques available at each stage. This view is supported by the fact that technical progress continuously improves and ultimately replaces existing machines - normally with faster and more automated alternatives. New machines, however, often cost more than older pieces of equipment for quite extended periods of time. They can also require more skilled labour and - like the air jet loom which weaves twice as quickly as the automatic loom, but wastes more cloth in the process - be more profligate in their use of material. For these reasons new machines do not on coming into production instantaneously displace existing machines. Instead, often for long periods, they increase the range of choice.

A production process then, in general consists of a number of separate, identifiable, sub-processes at each of which different sub-techniques may be used. In the brewing of beer, for example, the intake of raw materials, fermentation and beer filtration are separate sub-processes at each of which different methods of production may be employed. A sub-technique is a combination of inputs, some of which are fixed in equipment and last over all or a substantial part of the project, and some of which take the form of flows - like labour services and materials. A technique for any given industrial process comprises a combination of sub-processes (together with overhead provision which is for the present ignored). Suppose that two techniques of producing the same product are seen in use and that each of these comprises three separate and technically independent sub-processes - A, B and C. The two techniques and their sub-techniques are fully independent of each other, the number of techniques available is greater than those observed. In this example, the number of alternative techniques is eight - two of which are those observed and six are synthetic in that they are put together by mixing the sub-techniques that have been seen, but not in the combination in which they are now represented. For instance, $A_1+B_1+C_2$ is one synthetic technique, $A_2+B_2+C_1$ is another. More generally, if n is the number of techniques in use, and m is the number of sub-processes then - provided no two sub-techniques are the same - the total number of techniques which exist is n^m, of which n^m-n are synthetic.

To see the power of this method of identifying alternative techniques (and also to capture the realistic possibilities) consider the production of grey cotton cloth - a common good in developing countries. This is organized in eleven stages: opening and cleaning; carding; drawing; roving; spinning; cone winding; warping; slashing; drawing in; pirn winding;and weaving. It is convenient to number these stages, in the order given, from 1 to 11. It also necessary to allow for the fact that the number of stages is itself affected by the choice between ring and open-end spinning and between shuttle and shuttleless looms. Moreover, if open-end spinning is used then it is normally thought profitable to use manual doffing. Again, if open-end spinning is used then the type of draw frame required is different from that suitable for ring spinning,so that once the choice of spinning method is made there is no choice of drawing frame. Account may be taken of these factors by grouping the eleven stages in a way that reduces their number to seven. Thus, opening and cleaning, carding, warping, slashing and drawing in are all still considered separately. The remaining stages are taken in two groups: drawing up to and including cone winding; and pirning and weaving. In the first group there are fifteen alternatives currently available - twelve associated with ring and three with open-end spinning. In the latter there are eight options - five shuttle loom choices (allowing for the fact that pirn winding can be avoided if unifil equipment is used) and three alternative shuttleless looms.

The number of alternatives by stage may be tabulated as follows:

Stage(s)	No of Alternatives
1	6
2	1
(3 + 4 + 5 + 6)	15
7	1
8	1
9	3
(10 + 11)	8

so that the total number of techniques to be considered is 2,160.

In similar fashion it is possible to show that in the annual production of 300,000 pairs of men's shoes with leather upper and cemented-on synthetic soles the choice of alternative techniques runs in to the millions. In the production of lager beer 77 sub-processes may be identified. At six of these no effective choice of sub-technique exists, at eleven between four and six alternatives are to be found and in the remainder there are two-three alternatives. In the manufacture of solid clay-fired common brick four stages of production may be distinguished. At the first of these, winning the clay, there are at least five alternatives which could be considered; at the second, preparation of the clay and brick forming, at least a dozen options present themselves; at the third stage, the drying and handling of the bricks, there are six options; and at the final stage of firing and the removal of the bricks from the kiln, there are five choices. Again, in the process of leather manufacture there are fifteen distinct stages at most of which there are two or more choices of sub-process techniques.

This apparently plentiful supply of alternative techniques might be thought to be a characteristic of the particular industrial processes mentioned. In the batch manufacture of bolts and nuts, however, the range of choice is still impressive. Even when attention is confined to three different technology types - machining (on lathes), cold forming and hot forging - choices arise from the fact that the machines being used within each technique differ in respect of speed, automation and flexibility. Moreover mixes of two or more technology types within one factory are possible - and indeed in view of the nature of the batch industry and the differing requirements for different size bolts are likely to be advantageous. Again, in common with the processes already mentioned, machines with specific characteristics are frequently available from a range of manufacturers in developed and, often enough, developing countries.

(b) Least-Cost and Other Techniques

It is clear that for the processes mentioned (and in fact others) the scope for choice is very considerable. Moreover, the range of techniques is normally correspondingly wide - stretching, for example, in textile weaving from the modern, high-speed projectile loom to the 3,000 year-old, very simple, pit loom.[13/] Lack of choice is consequently not apparently a constraint on the search for an optimum technique, if this is construed as least-cost and, in some cases, capable of meeting the world price. Indeed for purposes of evaluation the choice sometimes seems embarrassingly great. Fortunately (least-cost) choices can be made for each sub-process, so that the need to undertake evaluations of many alternative, complete, techniques can be avoided. This is not to say that evaluation is thereby easy. Every investment decision should be location specific and so incorporate (realistic) assumptions about, for example, machine and labour productivity.[14] Establishing such assumptions, particularly for labour, is difficult. It is not, however, impossible; and discounted cash flow analysis applied to sub-processes can be used first to identify the least-cost technique in given circumstances and second to permit comparison between this and other selected techniques.

The possibilities in this regard may be illustrated by reference once more to textiles. One study[15] which took account of observed machine and labour efficiency concentrated on choices from the full range for the UK and for three representative LDC wage areas. The 'high' wage regime was taken as broadly that of Latin America and Hong Kong; the 'medium' regime that of countries at about the Ghanaian level of development; and the 'low' regime that of the least developed. The product in question was grey cotton cloth,[16] and the level of output some 28 million yards per annum, so that technical economies of scale were fully realized. The main results of the study are summarized in Table 1 which covers three techniques: the least-cost, the most capital-intensive, and the most labour-intensive. From the table it may be seen that the manufacture of cloth appeared profitable in all three developing areas, but most so in the low-wage regime.[17]

For each wage area, Table 1 compares the least-cost with the most capital- and most labour-intensive techniques. It

Table 1

NET PRESENT VALUES, CAPITAL AND OPERATING PRESENT VALUE COSTS AND EMPLOYMENT ASSOCIATED WITH SELECTED TECHNIQUES CAPABLE OF PRODUCING 28 MILLION YARDS OF COTTON CLOTH PER ANNUM IN FOUR WAGE AREAS AT A 10 PER CENT DISCOUNT RATE AND 20-YEAR PROJECT LIFE

Characteristics \ Technologies	Least-cost	Most capital-intensive	Most labour-intensive
1. Discount rate	10 per cent	10 per cent	10 per cent
(a) United Kingdom			
2. Net present value (US $000)	-	-	- 23,708
3. Capital costs (US $000)	19,289	19,289	11,380
4. Operating costs (US $000)	85,248	85,248	116,865
5. Employment (No.)			
Total	240	240	754
skilled	66	66	87
unskilled	174	174	667
(b) High-wage area			
2. Net present value (US $000)	35	-281	- 7,389
3. Capital costs (US $000)	22,113	22,113	12,920
4. Operating costs (US $000)	82,389	82,705	99,006
5. Employment (No.)			
Total	392	368	860
skilled	97	100	106
unskilled	295	268	754
(c) Medium-wage area			
2. Net present value (US $000)	3,127	- 1,007	407
3. Capital costs (US $000)	18,496	23,695	13,543
4. Operating costs (US $000)	83,008	80,735	90,587
5. Employment (No.)			
Total	872	674	1,769
skilled	196	223	247
unskilled	676	451	1,522
(d) Low-wage area			
2. Net present value (US $000)	5,470	- 113	- 2,036
3. Capital costs (US $000)	13,392	24,072	13,173
4. Operating costs (US $000)	85,675	80,567	88,728
5. Employment (No.)			
Total	3,004	1,486	3,499
skilled	428	401	428
unskilled	2,576	1,085	3,071

thus establishes that the least-cost technique in the UK is also the most capital-intensive; and in the high-wage area the least-cost and the most capital-intensive are very close. In the medium-wage area the least-cost technique is intermediate between the most capital- and the most labour-intensive; and in the low-wage areas, the least-cost is quite close to the most labour-intensive. It is worth noting that each of the techniques in the least developed countries has an absolutely greater skill requirement than in the UK. It may also be calculated from the table that the proportion of the most labour-intensive manning requirements met by the least-cost technique would be 45, 49 and 85 per cent in the high, medium and low wage areas respectively. Thus, overall, the results are pleasing. At a level of production likely to help minimize unit costs, the optimal technique more nearly produces 'maximum' employment the poorer the country.

The alternative techniques considered are 'synthetic' in the sense that,although they comprise sub-techniques which are generally observable in use, they are not necessarily to be found to be in working practice as complete processes. They are nevertheless robust and feasible, so that,if widely repeated for other industries, the foregoing results would be encouraging, without necessarily being entirely satisfactory in their employment implications. Generally speaking unit costs are likely to be lowest when economies of scale are fully exploited, and the higher the output the more capital-intensive techniques are likely to be preferable to labour-intensive ones. Thus in looking for replication of the textile results it is useful to confine attention to relatively large-scale activities. In this regard attention may first be given to iron founding where annual outputs of 1,000, 4,000 and 12,000 tonnes of 'good' castings provide the basis for the industry's own classification of small, medium and large foundries.18/ For an annual output of 12,000 tonnes, the net present values of alternative techniques - at prices and costs broadly of the Indian sub-continent and over a 20 year project life - at various discount rates, are as shown in Table 2.

Table 2

NET PRESENT VALUES AND EMPLOYMENT OF ALTERNATIVE FOUNDING TECHNIQUES

Technique	No. Employed	Net Present Values at 5 per cent	at 10 per cent (in £ 000's)	at 30 per cent
Hand Moulding	281	30,180	18,222	8,696
Mechanized Moulding	206	30,508	18,354	8,688
Conventional Automated Moulding	198	30,422	18,266	8,602
Flaskless Automated Moulding	196	30,282	18,136	8,481

From the table it may be seen that at all but an unreasonably high discount rate the hand moulding technique - which provides most employment - does not quite match mechanized moulding in profitability, although it comes close to it. At the small- and medium-scale, however, hand moulding would be generally chosen.

Another process which has been studied in relation to the choice of technique is that of mill-white sugar manufacture. Here argument has been made that, when high levels of output - say 50,000 tonnes of sugar per annum - are considered, the most capital-intensive variants of modern vacuum-pan techniques should be used. Thus one investigation[19/] which focused on Ghana found that even when shadow prices were used the results of Table 3 were obtained.

Table 3: EMPLOYMENT, CAPITAL-LABOUR RATIOS AND NPVs OF ALTERNATIVE SUGAR TECHNIQUES

Technique	No. of Employees	K/L (In Cedis)	Net Present Value (¢ Million at 10 per cent)
1	1,030	7,874	32.8
2	1,054	7,608	32.6
3	1,409	4,923	32.6
4	1,796	4,425	31.3
5	1,680	3,682	24.6
6	2,474	3,099	25.6
7	2,589	2,953	25.3
8	2,614	2,891	25.1
9	2,118	2,609	14.5

The iron founding and sugar results - although drawn from studies which confirm that there are choices of technique - are, on the face of it, less encouraging than those for textiles. On closer inspection, however, one need not be too despondent. It is apparent from the data presented on iron founding that the range of profitability across the techniques considered is narrow and relatively much less than that for employment. The same is evidently true of sugar, where technique 4 would provide some 74 per cent more employment than technique 1, but earn more than 95 per cent of its profit.[20/] These findings are of some generality and readily understandable when it is recognized that capital and labour combined account normally for considerably less than

50 per cent of the present value of total costs. It is thus not surprising that profitability should vary less across techniques than investible funds and employment, so that the trade-off between profitability and employment could often be acceptably small. Encouragement is consequently restored to the results.

Before considering some policy questions which are suggested by results of the kind described, it is useful to examine one or two aspects of the evidence more closely. It is widely believed that techniques used in developing country industry are often delivered on a turn-key basis. This it is assumed, means that such techniques are capital-intensive. Given this it is worth explicitly remarking on possible consequences of choices of this kind. This may be done by reverting to the textile results given in Table 1. From these it is clear that if, for example, the most capital- intensive technique were installed in a low-wage area, the profit (over the project life) of US $5.5 million which would be generated by the least-cost technique would become a loss of US $113 thousand. Moreover, the investment costs for a factory would be almost 80 per cent higher and employment some 50 per cent lower than if the least-cost technique were used. These figures suggest that critical choices are worth making.

In the light of what was said earlier about costs per work-place, it is of interest to consider investible funds per worker associated with the least-cost and capital-intensive technique.

From Table 1 these may be put, for the low-wage area, at US $4,458 and US $16,200 respectively. The ratio of these figures is 27.5 per cent, so that the suggested target of less than 25 per cent is within reach. A capital-labour ratio of US $4,458 is still, however, more generous than many poor countries could afford to pay in equipping their labour forces. The evidence deployed so far largely relates to modern technology. Given a capital constraint, however, it is pertinent to ask whether there is any efficient scope for more traditional, and generally much less capital-intensive, techniques.

(c) Modern versus Traditional Techniques

In this regard attention may once again be turned to textiles and sugar. In textiles, hand-spinning and hand-weaving organized as a cottage industry are no match for modern methods. Improved versions of these would do better if organized on a factory basis - probably, to exploit technical economies of scale, with an annual capacity of 200,000 yards of cloth. They would do even better still if advantage were taken of improvements made to traditional techniques by the Indian Appropriate Technology Association. These would achieve their technical optimum at an output of 1.2 million yards per annum. Some comparative data, for Indian conditions, are given in Table 4. The calculations underlying the table assumed a discount rate of 10 per cent and a project life of 20 years. They were made net of taxes and subsidies but were otherwise based on market prices. Techniques A to E in the table are modern, and the first five rows quantify the economies of scale.

Table 4

PRESENT VALUE COSTS AND EMPLOYMENT IN THE PRODUCTION OF 28 MILLION YARDS OF CLOTH PER ANNUM WITH SELECTED TECHNOLOGIES AND FACTORY SCALES

Mill	Present Value costs ($ 000)	Employment (No.)	Present value cost in excess of minimum ($000)	Increase in employment over least-cost (No.)	Cost per additional job compared to least-cost ($)
A (1)[a]	100,240	3,024	-	-	-
B (1)[a]	102,480	2,094	2,240	70	32,000
C (4)[a]	105,560	3,198	5,320	174	30,574
D (20)[a]	136,640	4,410	36,400	1,386	26,263
E (40)[a]	169,960	5,818	69,720	2,794	24,953
F (140)	319,480	47,488	219,240	44,464	4,931
G (24)[b]	140,560	11,337	40,320	8,333	4,838

a With ordinary looms - i.e. power driven but non-automated shuttle changing.

b More exactly, 23.33. In making the PVC and employment calculations the relevant figures for one-third of a factory have been taken on a pro-rata basis.

Key: A = 28 million yard factory; B = 14 million yard factory; C = 7 million yard factory; D = 1.4 million yard factory; E = 700 thousand yard factory; F = Hand-operated factory; and G = 'intermediate' factory. The numbers in brackets refer to factories required to produce 28 million yards. Hand-operated and intermediate factories are described in paragraph 34.

From Table 4 it is clear that neither hand-operated nor intermediate factories would be optimal choices. Both could, however, provide much more employment per unit of output than any of the modern factories and do so much more cheaply than any sub-optimal modern method. Yet the cost per additional job - almost US $5,000 - seems unduly high for a country with a per capita income of about US $100, so that these options should be ruled out. The use of market prices in the comparative evaluations could cause unease. The larger mills considered are likely to be located in or near urban areas, the smaller factories in rural ones, so that - given imperfections - the 'market' wages could differ in the two sectors. There are also the familiar arguments which underpin shadow pricing and would call for a revaluation of labour and other inputs in both sectors. In convenient, if somewhat pragmatic, recognition of these arguments Table 5 compares the modern technically optimal factory with the hand operated and 'intermediate' operations: (a) when 'market' wages are paid by the large factory and 50 per cent of those in the smaller sector; (b) where wages are reduced by half in all factories.

Table 5

COSTS AND EMPLOYMENT IN MODERN, HAND-OPERATED AND 'INTERMEDIATE' FACTORIES IN PRODUCTION OF 28 MILLION YARDS OF CLOTH PER ANNUM AT DIFFERENT WAGE RATES

Factory type / Cost and employment	'Modern' factory full wages	'Modern' factory half wages	Hand operated factory half wages	'Intermediate' factory half wages
PVC of cloth per yard ($)	3.58	3.12	7.25	3.83
Employment (no.)	3,024	3,024	47,488	11,357

Changing the wage rates in this way clearly helps the small-scale activities. The unit cost of the hand-operations is still unacceptably high. The position of the 'intermediate' is, however, much more marginal than before. If differential wage rates were in order, then the use of 'intermediate' methods would increase employment for the production of 28 million yards of cloth by 8,333 at a cost per job of US $840. If wages in both the modern and 'intermediate' factories were the same but shadow priced, then the cost of creating an additional workplace would be US $2,386. Perhaps the safest conclusion to draw from these figures is that it could be rewarding to undertake more research and development on the traditional processes.

An important limitation on the work on sugar discussed above is that it was confined to the factory. Sugar production, however, involves an extensive agricultural operation which itself produces an output (cane) for which no feasible alternative market other than processing currently exists (except at very low levels of output, when the cane is chewed directly by humans or fed to cattle). Moreover, once cut, sugar cane deteriorates at such a rapid rate that it has to be processed in the immediate vicinity of the fields. Interaction between field and factory is therefore of relevance to any investigation of the manufacturing process. A later study took this into account and, in selected African conditions, compared the efficiency of the modern vacuum-pan technique with that of the more traditional open-pan technique.[21] Two seasons were considered and both were evaluated for rainfed and irrigated agriculture. Four levels of output were studied: 100 and 200 tonnes of cane per hour (for the vacuum-pan factories) and 100 and 150 tonnes of cane per day (for the open-pan operations). In the long season, rainfed situation the 150 tonnes of cane per day factory would be the first choice at 5 and 10 per cent real discount rates and market prices. The larger of the two open-pan factories would however be preferable to the smaller of the vacuum-pan factories and would be sufficiently close to the largest factory in profitability to place the two in a small trade-off situation with respect to employment. Shadow pricing of labour, foreign exchange and the selling price of sugar gave the results shown in Table 6. From this it is evident that the larger of the two open-pan factories should now be chosen.

Table 6

ECONOMIC NET PRESENT VALUES FOR PLANTATION MODELS ON ALTERNATIVE ASSUMPTIONS (US$ PER TONNE OF SUGAR PER ANNUM)

	Discount rate (%)	
	5	10
Long-season, rainfed		
200 tch	1579	576
100 tch	1089	258
150 tcd	1870	904
100 tcd	1685	777

The sugar evidence is not conclusive. It does, however, rule out strong argument that there is little scope for open-pan techniques. On the contrary the evidence suggests that, in certain really identifiable conditions, some African governments at least should be encouraged to meet a demand for, say, 50-100,000 tonnes of sugar per annum by the establishment of a number of small, open-pan factories rather than by the erection of a single, large-scale, vacuum-pan plant. In this regard it should be noted that to obtain the same output - 110,000 tonnes of sugar per annum in a long season - as the 200 tonnes of cane per hour factory, would require 47 small-scale factories each with a capacity of crushing 150 tonnes of cane per day. The capital costs of these factories would in aggregate be considerably less than that of the single large factory. Moreover, the small-scale factories would provide employment for about 28,000 persons -

divided equally between factory and agriculture. This compares with a factory employment of 633 and a field labour force of 6,200 for the vacuum-pan process.

(d) Actual Choices

What emerges from the discussion is that there are choices available in a wide range of industrial processes from extant techniques. It has also been seen that, given the cost of not doing so, it is important that correct choices be made. The pertinent costs lower the profitability, raise necessary investment costs per factory, and lower employment per factory. For the economy as a whole the economic surpluses are less than they could be and the level of employment lower than would be possible. All in all, therefore, it is worth asking: are 'proper' choices made? Although this question has been around for a long time there is still surprisingly little in the way of systematic answer.[22/] There is, however, a strong presumption that developing country choices are more capital-intensive and sophisticated than they should be. This is supported by casual impressions and by some more rigorous studies. In this regard reference may be made to an investigation covering leather and sugar manufacturing in developing countries. For each of the industries a sample of between 20 and 30 factories was constructed with each sample covering 10 developing countries. The samples covered various levels of output, forms of ownership, and, evidently, locations.[23/] All of the factories in the sample were visited. Information was obtained which enabled realistic calculations to be made of the profitability of observed techniques and which supported calculations of the likely profitability of alternative techniques. Results from this investigation covering 12 leather and 12 sugar factories are given in Table 7.

It should be emphasized that the alternative techniques covered by the table were derived by making changes at a very limited number of sub-processes in each of the two industries, so that the results of the table do not capture the full benefits that would have accrued from a different choice of technique. Nevertheless it can be seen from the table that the use of a different technique would have generally increased the profitability of operations. It is also evident that fuller capacity utilization of the techniques than observed would have similarly increased profitability. In some cases the gains from more effective utilization of existing techniques exceed those that could be had from improved choice. The largest gains, however, obviously come from using better techniques to capacity.

III. Policies and Technical Progress

(a) Reasons for Inappropriate Choice

In considering policies to improve choices of technique it would obviously be helpful to know why 'wrong' choices were made.[24] This is not likely to be a simple matter. It can, however, safely be said that one explanation for inappropriate choice - a lack of alternatives - does not hold up.

A second explanation, foreshadowed in the earlier discussion of Figure 1, is that factor prices are 'distorted'. It would be difficult for most economists to gainsay the proposition that getting the factor prices right is important.

Table 7

ECONOMIC EVALUATION OF ALTERNATIVE TECHNIQUES

Leather Manufacturing

Factory No.	Discount Rate	Actual Tech. at observed capacity (Actual NPV)	Actual Tech. at Fuller capacity utilization	Difference from Actual NPV	Alternative Tech. at observed capacity utilization	Difference from Actual NPV	Alternative Tech. at fuller capacity utilization	Difference from Actual NPV	Fixed Investment		Employment (No.)	
									Actual Tech.	Difference with best alternative tech.	Actual Tech.	Difference with best alternative tech.
1.	10%	16	2,059	2,043	42	26	2,110	2,094	1,553	- 71	228	20
	20%	-945	-29	916	-902	43	30	975				
2.	10%	10	1,753	1,743	219	209	1,951	1,941	2,095	-215	256	23
	20%	-1,152	-441	711	-957	195	-251	901				
3.	10%	2,493	3,822	1,329	2,575	82	3,911	1,418	1,968	-120	232	18
	20%	50	580	530	142	92	673	623				
4.	10%	1,227	2,171	944	1,427	200	2,379	1,152	1,706	-159	195	8
	20%	-370	4	374	-205	165	174	544				
5.	10%	815	2,020	1,205	890	75	2,103	1,288	1,217	-88	151	9
	20%	-605	-66	539	-533	72	11	616				
6.	10%	1,289	1,289	0	1,315	26	1,315	26	522	-16	104	2
	20%	335	335	0	355	20	355	20				
7.	10%	-1.5	114	115.5	110	111.5	358	359.5	717	-240	103	8
	20%	-368	-321	47	-193	175	-95	273				
8.	10%	4,880	7,123	2,243	4,918	38	7,160	2,280	943	-18	148	4
	20%	1,665	2,625	960	1,696	31	2,646	981				
9.	10%	31,320	31,320	0	31,339	19	31,320	0	3,294	-12	255	3
	20%	12,163	12,163	0	12,176	13	12,163	0				

Table 7 (cont/d.)

Leather Manufacturing

Factory No.	Discount Rate	Actual Tech. at observed capacity (Actual NPV)	Actual Tech. at fuller capacity utilization	Difference From Actual NPV	Alternative Tech. at observed capacity utilization	Difference from Actual NPV	Alternative Tech. at fuller capacity utilization	Difference From Actual	Fixed Investment		Employment (No.)	
									Actual Tech.	Difference with best Alternative Tech.	Actual Tech.	Difference with best Alternative Tech.
10.	10% 20%	2,501 143	2,501 143	0 0	2,542 170	41 27	2,501 143	0 0	465	-30	104	5
11.	10% 20%	5,180 870	5,180 870	0 0	5,223 911	43 41	5,180 870	0 0	1,033	-27	164	4
12.	10% 20%	1,410 33	1,782 180	372 147	1,469 81	59 48	1,841 228	431 195	1,107	-50	129	8

Sugar Industry (there is no evaluation of alternative technology at fuller capacity utilization)

Factory No.	Discount Rate	Actual Tech. at observed capacity (Actual NPV)	Actual Tech. at fuller capacity utilization	Difference From Actual NPV	Alternative Tech. at observed capacity utilization	Difference from Actual NPV	Alternative Tech. at fuller capacity utilization	Difference From Actual	Fixed Investment: Actual Tech.	Fixed Investment: Difference with best Alternative Tech.	Employment: Actual Tech.	Employment: Difference with best Alternative Tech.
1.	10% 20%	-10,924 -10,050	-7,993 -8,544	2,931 -1,506	- -	- -			9,750	-	2,270	-
2.	10% 20%	-14,252 -19,433	-11,530 -18,121	2,822 1,312	-11,549 -18,025	2,803 1,408			23,229	-247	2,144	177
3.	10% 20%	-2,456 -14,241	- -	- -	-1,553 -13,898	903 343			22,588	405/ -805	3,591	-/ 498
4.	10% 20%	-23,589 -28,203	-20,682 -26,851	2,907 1,352	-22,705 -27,826	884 377			32,207	72	2,769	-

Table 7 (cont/d.)

Sugar Industry

Factory No.	Discount Rate	Actual Tech. at observed capacity utilisation (Actual NPV)	Actual Tech. at fuller capacity utilization	Difference From Actual NPV	Alternative Tech. at observed capacity utilization	Difference From Actual NPV	Fixed Investment		Employment (No.)	
							Actual Tech.	Difference with best alternative tech.	Actual Tech.	Difference with best alternative tech.
5.	10%	-1,747	-1,460	287	-1,356	391	3,190	63	829	-
	20%	-2,671	-2,537	134	-2,518	153				
6.	10%	-12,073	-10,770	1,303	-10,151	1,922	16,820	-1,731	3,160	-
	20%	-16,936	-16,330	606	-15,221	1,715				
7.	10%	-3,948	-3,328	620	-2,162	1,786	6,295	-314	962	-
	20%	-5,667	-5,379	288	-4,703	964				
8.	10%	-6,348	-5,057	1,291	-	-	3,693	-	1,063	-
	20%	-5,081	-4,460	601	-	-				
9.	10%	-4,408	-3,658	750	-3,492	916	6,065	-158	1,478	-
	20%	-5,616	-5,267	349	-5,115	501				
10.	10%	-3,906	-3,658	248	-3,383	523	5,002	45	1,294	-
	20%	-4,603	-4,488	115	-4,381	222				
11.	10%	-18,526	-7,731	10,795	-	-	14,382	-	n.a.	-
	20%	-16,042	-11,091	5,023	-	-				
12.	10%	-5,238	-4,678	560	-4,394	844	16,048	73	1,581	-
	20%	-10,363	-10,100	263	-10,005	358				

This is not the same thing, however, as saying that doing so would result in optimal choices of industrial techniques in developing countries. For a start it is not clear from the detail which underlies much of the evidence discussed in the last section that, say, UK-Ethiopian factor price ratios are sufficiently out of kilter as to provide an explanation for Ethiopian choice of, for example, more capital-intensive textile techniques than would be found in the UK. More generally, the view that getting the factor prices right is both a necessary and sufficient condition for optimal choices clearly relies heavily on the assumption of profit maximization. Particularly, however, in the imperfect economies of developing countries the scope for less than dedicated marginal pursuit of this objective is considerable. One way in which this is manifest is in the influence of the engineer. The engineer's instinct is to use, as a matter of professional pride and training, best-practice techniques. This instinct coincides increasingly with the aversion of many managers to a large and, in their eyes, troublesome labour force. Management has its own set of shadow prices and implicit collusion could have these survive a strengthening of competition. Thus, although the search for appropriate techniques may be presumed to be the more intensive the greater the degree of competition in the economy, it looks as if there are elements in the situation which could go beyond factor prices.

What, then, is to be done - beyond introducing more competition and encouraging sensible factor pricing? In a sense the greatest need is that of increasing the knowledge available to individual developing countries of the alternatives that are there. The costs of conducting the investigations that have provided most of the empirical material for this paper are relatively modest. It should, consequently, be possible for developing countries, acting severally or jointly, to establish groups which could assess the availability of techniques on a continuing basis. Such groups would have to acquire a competence in the financial and economic evaluation of industrial techniques; and the best way of doing this would be to undertake industry studies.

Even if the relevant knowledge were widely available and appreciated it would still have to be translated into policy influence. This is a more difficult matter and not one that can be legislated for in a general way. It may, however, be noted that in most developing economies the role of the public sector in industrial development is considerable.

(b) Technical Progress and the Choice of Technique

Like the literature of which it forms part, this paper has not been as sharply focused as would be desirable. Nevertheless it is hoped that its drift is clear. It registers and supports a view that better choices of industrial technique are possible than many that have been made in developing countries. Such improved choices would possibly move the 'average' choice much nearer the labour-intensive end of the spectrum than it now is. Insofar as this is so, there could be a fear that static choices of technique could lock a country into a pattern of technological development that would be unhelpful in the light of technical progress. It is not, however, clear that this would be so. Careful choice of labour-intensive techniques has until the present been an important element in the dynamic strategy of countries at one level of development wishing to move to a higher one.

Thus Taiwan in the early 1950s adopted an import substitution policy which was quite similar to that adopted by many other developing countries. While this policy was being followed,the population grew by about 3.6 per cent per annum. Manufacturing increased rapidly, imports of consumer goods fell absolutely and relatively, those of capital goods increased markedly, and exports increased modestly. After a decade Taiwan had a large deficit in international trade and had experienced but modest growth in employment, so that overt unemployment was estimated at 6 per cent and 'underemployment' at half of the labour force. The domestic market remained small, the natural resource base was poor, agriculture had come close to the limit of labour absorption and offered agro-industrial expansion, and the balance of payments constraint restricted the import of capital goods. In these conditions an extension of the existing import substitution policy to cover those consumer goods still being imported and intermediate and capital goods would have been difficult. Instead the policy adopted - in the light of surplus labour and low initial wage rates - focused on the export of labour-intensive manufactured goods with low capital-output ratios. In the event exports, total output and employment increased dramatically and by the mid-1970s full employment had been attained. A somewhat similar story could be told of

19th-20th century Japan and of the Republic of Korea since 1960.[25]

These telling tales do not dispose entirely of doubts induced by consideration of dynamic links between present choices of technique and subsequent technical progress. The view has been taken that contemporary factor prices determine the choice of technique which in turn - by a kind of learning by doing and using - greatly influences the pattern of research and development.[26] Considerably oversimplifying a complex argument, if static choices of technique were in developing countries to result in choices which were more labour- than capital-intensive then, since this is the environment in which challenges would present themselves, technical progress could be expected to consist largely of improvements at the labour-intensive end of the spectrum. Should this be cause for concern? That is, is this a likely outcome? And if so, should one worry about it.

In judging the likelihood of labour-intensive directed technical progress it should be noted that the view cited was originally advanced in a developed country context - and indeed as part of the continuing debate on the character of historical experience in the United States. It may consequently be less than fully relevant to developing countries where the capacity for research and development is anyway generally thought to be weak. Nevertheless, in so far as a capacity for research and development exists and/or can be developed,many would welcome an outcome that saw most of the effort devoted to improving and designing relatively labour-intensive techniques. Moreover, there is more to this than the missionary zeal of those who believe that small is always beautiful. In the circumstances of many poor countries labour-intensive processes would probably be more organically grounded than alternatives and so should develop more rapidly and more wholesomely in a number of directions. The use of such processes could create a large and rapidly growing artisan class and thus generate and sustain a demand for education of the kind that underlay the creation of the first technical colleges and mechanics' institutes in the now developed countries. If this demand were to be met it could have an impact, inter alia, on technical progress. In saying this it is necessary to recall that technical progress implies a saving in factor use, so that the presumption here is that there would be pressures to develop capital-saving techniques which it is assumed would also be labour-using but still, overall, cost reducing.

Given the above, there would seem to be little cause for dynamic concern if the international division of labour efficiently provides scope for the production of labour-intensive goods for domestic consumption and export in developing countries and if countries can readily enough move up the spectrum as circumstances change. Nevertheless, a stubborn critic might still confess to worry in the light of the electronics revolution that is widely thought to be upon us; and in the light of the speed with which that permanent revolution might proceed. Where, might the critic ask, is the scope for the labour-intensive in 'the factory of the future'? Where indeed is the scope for technically independent work-stations in the industrial process which computer-aided design, management and production has reduced to a continuously linked system of transforming inputs into outputs? One first response to these questions is another: where is the factory of the future, and when will it be a general phenomenon even in developed countries? Automation has not yet technically arrived, although it may come sooner rather than later. Technical feasibility is, however, one thing, successful commercial operation another; and there are reasons for thinking that the diffusion of automated techniques will take some time.[27/] The markets for labour-intensive products are not going to disappear overnight. Nor is the making of 'sensible' choices of technique within a limited time horizon likely *per se* fatally to inhibit the ability of a country to adapt to changing conditions. The labour-intensive origins of recent and rapid growth in some of the newly-industrializing countries has not prevented them from preparing to 'up-grade' their technological base and their production techniques.

NOTES

1/ The density as well of the size of the range is important. If there were only two choices, one very capital- and one very labour-intensive, the range would be great but the choice inadequate. The need, as will be seen, is for well-populated sets of techniques capable of manufacturing given products.

2/ For a discussion of this question in the context of Ethiopia see James Pickett, Development, Technology and Employment in Ethiopia, DLI Discussion Paper No. 4, University of Strathclyde, Glasgow, 1984.

3/ The theory in question is the long run neo-classical theory of the firm. The convexity of the isoquant (viewed from the origin) derives from the fact that the contribution of each factor to production is subject to diminishing returns. Thus as capital is reduced the loss of output per unit of capital increases, whereas labour use increases the increase in output per unit of labour is falling. It follows that as substitution proceeds - beginning from a lot of capital, little labour - it will require more and more labour to 'compensate' for a unit of capital. It is also evident that, since the marginal rate of factor substitution measures the rate at which one factor is being substituted for another with output held constant, that the marginal rate of substitution between two factors must equal the ratio of their marginal products. The formal condition for profit maximization is $MP_K/MP_L = P_K/P_1$, where MP is marginal product, P stands for factor price and the subscripts have their obvious meaning. Given that the MRS at any point is the slope of the isoquant at that point, it can easily be seen that the condition is met - twice over - in Figure 1.

4/ Ignoring transport costs.

5/ For a discussion of engineering influence see Pickett et. al., "The Choice of Technology, Economic Efficiency and Employment in Developing Countries", World Development, March 1974 and the paper by Wells in Timmer et al, The Choice of Techniques in Developing Countries, HUP, 1975.

6/ For a fuller discussion, see A.K. Sen, Technology and Employment, OUP, 1975.

7/ For a breakdown of capital and other costs see, for example, Pickett and Robson, The Choice of Technology in the Production of Cotton Cloth, Scottish Academic Press, Edinburgh, 1982.

8/ Sir Austin Robinson in Robinson (ed.), Appropriate Technologies for Developing Countries, Macmillan, 1978.

9/ The definition does not seem to be Keynesian. It contains no mention of demand, nor indeed does the paper from which it is extracted. Perhaps the developing countries are assumed to be neo-classical price takers, though even that seems far-fetched in relation to, say, textiles and footwear.

10/ For other relevant calculations and discussions see Frances Stewart, Technology and Underdevelopment, Macmillan, 1977.

11/ This discussion draws heavily on the work of the David Livingstone Institute, notably the following monographs: D.J.C. Forsyth, The Choice of Sugar Technology, HMSO, 1979; N.S. McBain, The Choice of Technique in Footwear Manufacture, HMSO, June 1977; J. Keddie and W.H. Cleghorn, Brewing in Developing Countries, Scottish Academic Press, 1979; M.M. Huq and H. Aragaw, Choice of Technique in Leather Manufacture, Scottish Academic Press, 1981; J. Pickett and R. Robson, The Choice of Technology in the Production of Cotton Cloth, Scottish Academic Press, 1982; and B.A. Bhat and C.C. Prendergast, Choice of Technique in Iron Founding, Scottish Academic Press, 1984.

For broadly similar conclusions see Bhalla and for a still useful, more general review, White, "The Evidence on Appropriate Factor Proportions for Manufacturing in Less Developed Countries: A Survey", Economic Development and Cultural Change, October 1978.

12/ R.S. Eckaus, "The Factor-Proportions Problem in Underdeveloped Areas", American Economic Review, September 1955; W.E. Salter, Productivity and Technical Change, CUP, 1966; and Frances Stewart, op.cit.

13/ Pit looms were not included in the earlier discussion of textile alternatives which was confined to modern methods.

14/ For a fuller discussion see, Pickett and Robson, op.cit., Chapter IV.

15/ ibid. The prices used in this study were broadly market prices, but net of all taxes and subsidies. The UK 'project' was taken as marginal and the selling price set such that the NPV there (at a discount rate of 10 per cent) was zero. The study covered the latter part of the 1970s.

16/ Of 20/20 English counts.

17/ Doubling the discount rate would render production everywhere unprofitable, but would not alter the rank ordering. Since the calculations were constant cost ones, the 10 per cent rate already represents a stiff hurdle. It may be noted that the competitive advantage of the poor countries does not seem to spring from low wages (which are largely offset by low productivity) but rather from their ability to grow cotton. See Pickett and Robson, op.cit. Chapter VII. The calculations of Table 1 are based on a price of cloth which makes the UK least-cost mill marginal - i.e. gives a zero NPV.

18/ What follows is based on Bhat and Prendergast, op.cit., It should be noted that product mixes may vary greatly across foundries at any point in time and within foundries over time. However, in this study the analysis is of a homogeneous product.

19/ Forsyth, op.cit.

20/ For a fuller discussion of this see Pickett, Editorial Introduction, ibid. The finding in favour of the capital-intensive has itself been challenged. See Alpine and Pickett, "More on Appropriate Technology in Sugar Manufacturing", World Development, Volume 8, 1980.

21/ For a fuller discussion see Alpine and Pickett, op.cit.

22/ For an early attempt to document the character of choices of technique see R. Hal Mason, "Some Observations on the Choice of Technology by Multinational Firms in Developing Countries", Review of Economics and Statistics, 1973. For other relevant works,which stretch to explanation, see Timmer et al. and Pickett, et al., op.cit.

23/ For a further discussion see Pickett and Robson, Efficiency in Technology Choice in Leather and Sugar Manufacturing in Developing Countries, DLI Discussion Paper No. 1, University of Strathclyde, 1981.

24/ Particularly if the promotion of employment is given a prominent place, the discussion of industrial technique should stretch to cover adaptation and design as well as choice. To some extent work on all three fronts can, and should, proceed simultaneously. The view taken here, however, is that there is much to be said for concentrating most of the initial attention on improved choice. Consequently the policy discussion in the text does not, by and large, go beyond the improvement of choice.

25/ For an interesting comparison of the Philippines and Taiwan see G. Ranis, "Appropriate Technologies in the Dual Economy",in Sir A. Robinson, Appropriate Technologies for Third World Development, Macmillan, 1979.

26/ A useful, more extended discussion of this question is in N. Rosenberg, The Black Box: Technology and Economics, CUP, 1983, Chapter 1.

27/ As a supplement to this admittedly cavalier treatment of an important and complex topic, see Rosenberg, ibid, Chapter 9.

Addendum

Some Implications of 'Improved' Choice of Techniques and of Technical Progress

The purpose of these notes is to enlarge on an earlier paper[1] by considering (a) some consequences of improved choice of industrial techniques, and (b) the implications for such choice of newly emerging techniques. These tasks are undertaken seriatim.

I. Consequences of Improved Choice

If it be granted that developing countries now use techniques that are more capital-intensive than their factor endowments dictate (and that efficient, labour-intensive, techniques are available), it is natural to speculate on the consequences of better choice. Such speculation has not yet resulted in any large volume of systematic results. Part of the difficulty lies no doubt in the fact that the consequences it is desired to capture are by definition hypothetical. Moreover effort has largely gone into the logically prior task of demonstrating that efficient, more-or-less labour-intensive, options can be found.

The staunchest effort to date to elucidate the employment and other economic implications of better choice of technique has been made by Pack.[2] Basing himself largely on the results of work done by the David Livingstone Institute, he has calculated the difference 'correct' choice would make in each of and in the aggregate of nine products - shoes, woven cloth, yarn, bricks, milled maize, processed sugar, beer, leather, and urea. The benefits are evaluated in terms of investment, value-added and employment, and are derived from a comparison of the

---

1/ James Pickett, The Choice of Industrial Techniques in Developing Countries, May 1985.

2/ Howard Pack, Macroeconomic Implications of Factor Substitution in Industrial Processes, World Bank Staff Working Paper, No. 377, Washington, 1980.

characteristics of the most capital-intensive and the 'optimum' technique considered in each primary study. The 'optimum' technique is that which maximizes the ratio of net present value to capital (NPV/K).

The method used assumes that US $100 million is to be invested in each sector without changing either factor or final product prices. It is, moreover, claimed that the product mix is representative enough of that prevailing in the poorer LDCs. Plant size is taken in each case to be that which realizes technical economies of scale. Production, however, is taken as being highly divisible, so that US $100 million can be exactly exhausted in investment in both capital-intensive and 'appropriate' techniques in each sector.

The main results of Pack's calculations are set out in Table 1. These suggest that the benefits from improved choice would be considerable. To produce a given level of output the investible funds needed by the capital-intensive technique in each sector would be higher than those associated with the 'appropriate' one; and employment would be lower, so that the capital-labour ratio is generally higher in the capital-intensive mode. Given this, it is not surprising that US $100 million invested in each sector would give rise to significantly higher employment across the board if the 'appropriate' rather than the capital-intensive technique is chosen. Even in the generically capital-intensive business of making urea, the increase would be almost 12 per cent. The relatively labour-intensive technique would provide higher value-added and have a higher proportion accrue to capital than the alternative technique in each sector. Taking all sectors together, the use of 'appropriate' techniques in each would increase value added by 71.6 per cent and employment by 311 per cent.

TABLE 1: CHARACTERISTICS OF CAPITAL-INTENSIVE AND 'APPROPRIATE' TECHNIQUES IN PRODUCTION OF SELECTED PRODUCTS

Product	Plant Size[a]	Investment per Plant				Annual Consequences of US $100 million investment					
		K		K/L		Value Added		Non-labour income		Employment	
		A	B	A	B	A	B	A	B	A	B
		US $000s				US $000,000s				numbers	
Shoes	300,000 pairs	165	334	0.8	2.2	88.99	68.12	73.19	59.04	31,589	18,158
Woven Cloth	40 million yds.	4,715	9,779	8.7	37.6	23.44	4.80	18.20	3.61	10,488	2,538
Cotton Yarn	2,000 tonnes	480	1,440	2.0	14.7	57.98	34.26	52.61	32.00	10,747	4,525
Bricks	16 million	796	3,437	3.3	45.8	55.67	-4.41	40.75	-5.50	29,909	2,182
Maize	36,000 tonnes	219	613	2.9	9.7	23.10	12.09	13.48	8.30	19,231	7,574
Sugar	50,000 tonnes	3,882	6,386	0.8	6.2	247.66	162.80	185.68	154.84	123,980	15,925
Beer	200,000 hecto-litres	2,809	4,512	12.1	18.3	52.39	23.89	48.66	21.73	7,460	4,316
Leather	600,000 hides	4,832	6,692	15.5	36.2	19.74	11.77	17.49	10.72	4,502	2,108
Urea	528,000 tonnes	29,597	34,132	122.3	137.6	54.95	50.11	54.57	49.76	772	691
All	-	47,495	67,325	6.68	28.52	623.92	363.51	504.60	334.50	238,678	58,017

Legend: A = Capital-Intensive

B = 'Appropriate'

Source: Pack. *op.cit.*, Tables 2 and 3.

a/ Annual Output.

The industry studies on which Pack largely draws (and others on which he does not) carry the implication that the choice of technique could be improved in ways that would save on the use of investible funds, generate more employment and either increase profitability or at least require marginal sacrifice in this regard. If more careful scrutiny could be introduced, benefit would follow. This much, to repeat, is clear from the industry studies. Does Pack's attempt to calculate the macro-economic gains take matters much further? In this regard it has to be said that the calculations are subject to powerful reservations. Pack himself recognizes that the 'wrong' techniques chosen do not necessarily lie, as it were, right at the capital-intensive end of the spectrum, so that gains are maximum ones. He also recognizes, rather casually, that value added (at least by labour) through better choice would have to be diminished by the opportunity cost of the extra workers in the selected sectors. There are, however, other reservations.

It may be doubted if casual simulation will really serve in such complex circumstances. Moreover, the definition of the 'appropriate' technique (NPV/K) derives its justification from an artificially-imposed capital rationing constraint - and even then it is difficult to give formal justification for it.[3/] Again, the Strathclyde studies used by Pack do not identify the technically optimum size of plant.[4/]

II. Emerging Techniques

It is widely - if not always correctly - supposed that developing countries have a comparative advantage in the use of labour-intensive techniques, since they enjoy lower

3/ For a fuller discussion of this, see Pickett, Report on a Pilot Investigation of the Choice of Technology in Developing Countries, Glasgow, 1975, Chapter 3.

4/ Ironically the one Strathclyde study which does - textiles - is not used by Pack.

labour costs. If the processes of which this is now true were to be automated in the developed countries, would this lead to a switch in comparative advantage? This question illustrates the kind of fear that is expressed on behalf of the developing countries about technical progress. Unfortunately little systematic investigation has been made of the basis for this fear.

That significant changes - affecting not only industry, but also agriculture and services - are afoot cannot be gainsaid. The microelectronic production, processing, transmission and storage of information is having a marked impact on industrial processes. In some cases it has led to reductions in labour costs, improved management, better product design and quality control, and so, it would seem, threatened developing countries using conventional techniques, low labour costs and abundant natural resources - in textiles and leather goods for example. The gains from natural abundance are further threatened by developments in material technologies - the substitution, for example, of optical fibres for copper in telecommunications is not evidently good news for Zambia and Zaire.

It is, however, wrong to see only threat in the new techniques. Some LDCs - such as South Korea and Taiwan - may more easily, given their institutional framework and relatively docile labour forces, effectively exploit the new opportunities than some at least of the developed market economies. And some of the new products and materials required may be suitable for LDC production. It is probably too early to draw up a balance sheet in these regards. This is particularly true of biotechnologies - based on developments in molecular biology, biochemistry and genetics - since by and large these have not yet moved from the laboratory to the point of production.

June 1985

CHAPTER V

DEVELOPMENT AND MANAGEMENT OF TECHNOLOGICAL CHANGE IN INDUSTRY

The contribution of the Industrial Development Unit and an outline of some future perspectives for developing countries

Industrial Development Unit,
CFTC,
Commonwealth Secretariat,
London.

September 1984

DEVELOPMENT AND MANAGEMENT OF TECHNOLOGICAL CHANGE IN INDUSTRY

Contents

I. Technology Transfer in IDU Assisted Projects

Since its inception in 1980/81, the Industrial Development Unit (IDU) has extended technical assistance to Commonwealth developing countries, at their request, in almost forty industrial sub-sectors (see Table 1 on page). Food processing accounted for the largest single number of projects (over one-fifth of the total), assistance being given to the processing or refining of sugar, vegetable oils,meat, fruit and vegetables, and salt. Non-metallic mineral products (e.g. ceramics,glass, cement and bricks) and metal products (e.g. cans, wire products, sheet metal and other light engineering products) each accounted for 10 per cent of the total, as did projects in the chemicals, textiles, and machinery and transport equipment sectors. Over three-quarters of the projects were in the least developed and small island countries of the Commonwealth and all were small in scale.

The projects have included introducing processes, materials and products new to the recipient countries. IDU has been involved in pre-investment and feasibility studies, selection of technology, joint venture participation, technical services for engineering and plant commissioning, development of entrepreneurship, and transfer of technology and provision of related training.

Technology transfer from Commonwealth sources for development and implementation of projects is a cardinal feature of IDU's catalytic role. Such transfers have been effected through the preparation of engineering drawings or process charts, adaptation of commercial technology,'on-the-job' training, and simulation and testing of engineering models for commercial production according to the needs, skills, resources and markets of host countries.

In the development of seaweed industries in Tonga and Fiji, for instance, the proven R&D expertise of a commercial source in another Commonwealth country was utilised to develop products suitable for the marine resources of these islands. Similarly, for solar salt projects in several Commonwealth countries, IDU drew on specialised engineering expertise in the Commonwealth for designing solar salt pans, and checking brine density. Suction glass forming technology was similarly derived, and adapted for small-scale operations in countries with limited markets for glass products. Commonwealth technology inputs were also critical for the development of ceramic industries in Guyana and Uganda.

In several instances, more complex technologies had to be identified from appropriate sources and transferred to projects on which IDU's assistance was required to ensure commercial viability. Illustrations include the assistance given in developing computer-aided design and manufacture (CAD/CAM) for upgrading small-scale automotive parts manufacturing in India, microelectronics applications for small industries in Malaysia, the electrolysis process for ammonia-based fertilisers in Malawi, and the production of sulphuric acid for detergents in Jamaica.

Table 1

INDUSTRY DISTRIBUTION OF IDU-ASSISTED PROJECTS
1980/81 - 1983/84

ISIC Group	Industry Sub Sector	No. of Projects
01	Agriculture	2
20	Food processing	76
21	Beverages	9
22	Tobacco processing	1
23	Textiles	30
24	Footwear	2
25	Wood and cork products	19
26	Furniture and fixtures	4
27	Paper and paper products	13
28	Printing and publishing	2
29	Leather and leather/fur products	14
30	Rubber products	4
31	Chemicals and chemical products	31
32	Products of petroleum and oil	-
33	Non-metallic mineral products	36
34	Basic metal industries	14
35	Metal products	36
36	Machinery (non-electrical)	8
37	Electrical machinery & appliances	11
38	Transport equipment	13
39	Miscellaneous manufacturing industries	10
		335

Complex process and instrumentation controls were designed for the sugar industry in Trinidad and Tobago which has also requested assistance in the development of an electronics industry.

Technology and specialised expertise have been used from both developing and developed countries. They include Antigua and Barbuda, Australia, Barbados, Britain, Canada, Cyprus, Guyana, Grenada, India, Jamaica, Malawi, Malaysia, New Zealand, Nigeria, Singapore, Sri Lanka, St.Lucia, Swaziland, Tanzania, and Trinidad and Tobago. R&D institutions in Commonwealth countries have also given advice.

In IDU's future programme approved by Commonwealth Ministers of Industry in August 1984, it is recognised that technology will remain a key input in the implementation of industrial projects in Commonwealth developing countries. This is as true of the provision of basic needs - food, clothing, shelter, energy, transport, health and education - as it is of, say, mining, smelting and engineering.

Most Commonwealth developing countries are seeking to raise their self-reliance in food processing. This is typified by projects directed at, for example, implementing a beef industry (Antigua and Barbuda), undertaking fruit processing (The Gambia and Grenada), refining edible oils (The Gambia and Sierra Leone), and carrying-out fish processing (Kiribati, St.Lucia, Seychelles, Tuvalu and Vanuatu). In clothing, the range of projects to be assisted includes those intended to produce dyestuffs and dyed cotton (Bangladesh), sea island cotton (St.Christopher-Nevis), ready-made garments (Sri Lanka), and footwear and leather products (Botswana, Uganda, Tanzania and Western Samoa). Housing projects include the proposed production of chipboard and PVC tiles in Fiji, clay products in Botswana, and ceramics in Solomon Islands. In energy, assistance will be given to developing solar systems (including photovoltaics) and mini-hydro systems, to energy conservation and management (including evaluation of wood-stoves, use of coconut oil in place of diesel oil, and of retro-fitting boilers for biomass fuels) and to other projects helping small countries to reduce their dependence on imported energy. The projects include the manufacture of specialised appliances for solar refrigeration, photovoltaic electric lighting and water pumping in Cyprus, Kiribati, Sri Lanka, and Solomon Islands. Assistance in the production of pharmaceuticals to support basic health services is envisaged for Malta, Nigeria, and Swaziland. As regards education, help will be given for paper production in Dominica and Zimbabwe and for colour printing in Tonga. Assistance planned for projects involving high-tech microprocessor controls in the automotive industry in India and Malaysia and an increase in the local content of motor vehicle assembly in Zimbabwe typify efforts directed at the basic needs area of transportation.

Help in the development of mineral industries will be important in several member countries including Barbados, Cyprus and Malaysia. Light engineering industries will be of prime interest to countries such as Malta, Mauritius, and Trinidad and Tobago. Projects for reactivating, upgrading, modernising and expanding existing industries continue to be emphasised by countries such as Jamaica, Uganda, Tanzania, Ghana, Zambia, Nigeria, Kenya and Zimbabwe, which possess relatively developed industrial bases.

II. Technology for Commercial Projects in Developing Countries

Criteria for selection

According to the memorandum setting it up, the IDU is required to assist in the development of bankable commercial projects. As in the case of most industrial projects in developing countries, these are financed by development banks and by commercial banks which may insist on internal rates of return of 15 per cent or more. Apart from the need for financial viability, technology selection involves more than choosing the labour-capital proportions of a given process. Labour and capital are not homogeneous production factors, so that not two, but many inputs must be considered. There are many types of capital goods, some serving only one function, but many having alternatives. Skilled labour inputs are human capital. Capital-intensive technologies may not necessarily create less employment than labour-intensive technologies, if the technology uses capital goods manufactured with a high labour content. Furthermore, for a given capital-intensive technology, the rate of savings may be higher than for an alternative labour-intensive technology, given higher marginal rates of saving for private or government owners of capital than for workers or proprietors of small enterprises. As a result, future employment as well as future income may be higher with such technologies. In other words, there may be a trade-off between present and future employment. Factors such as scale, capacity utilisation and plant location also need to be evaluated. Consequently there can be no rigid rules about the types of technology applicable to particular countries.

Need for scientific and technological capacities

Technology selection in developing countries, as in others, has to take account of new techniques and processes. Advances in a number of fields such as genetic engineering, biotechnology and microelectronics have far-reaching implications on the growth and pattern of industrial production, technology transfers and employment. Many of these advances derive from basic scientific research and are relatively sophisticated, but their industrial applications are relatively simple. According to UNIDO, about two-thirds of the industrial production of developing countries could be affected by these technological advances. Microelectronics, for example, will have a major impact on the engineering, printing and clothing industries, while biotechnology will impact on the chemical, pharmaceutical, food processing and energy industries.

UNIDO studies stress that high-technology is not an escape route from the problems of development but only a part of the available technology options, which range from the traditional to the advanced. In an interdependent world, the developing countries cannot be left in technological isolation. They ought to have access to all types of technology and not merely to the simpler varieties. The basic technology used in developing countries has to be upgraded. Each country thus will have a combination of technologies that will be optimal in the light of its objectives, problems and constraints, including the skills and capabilities of its people who are ultimately both the creators and the beneficiaries of technology. Small industries, small energy systems (including mini-hydro units) and agro-industries are some of the areas that could be upgraded through application of advanced technologies. The viable introduction of scaled-down technology is especially relevant for small states and least developed countries where industrial development is particularly difficult because of small markets, meagre resources and scarce skills.

Some developing countries have emerged with a large pool of scientific and technological manpower through the steady process of education and training, and through institution-building such as the establishment of science parks. Most developing countries, however, lack technological services. These services range from macro-level industrial planning to micro-level project identification, feasibility studies, plant specifications, detailed engineering designs, civil construction and machinery installation, and the commissioning, start-up and operation of plants.

The injection of technology inputs appropriate to each project has been a key feature of the IDU's work. Such inputs have ranged from the traditional technology of coir weaving, oil milling and furniture making, to the application of microelectronics and specialised technological designs for small-scale projects on a commercially viable and economically efficient basis.

Basic engineering and design capability has been a significant gap in many developing countries, making local control over imported technology packages extremely difficult. In responding to these gaps, IDU undertakes field work in association with local personnel who thus receive some measure of training 'on-the-job'.

Application of advanced technology is seen as a major goal of international cooperation for development in the 1980s and 1990s. By solving problems in the fields of health, water and sanitation, these technologies would enable the benefits of development to reach down to the poorest. 'Technologies for Humanity' could thus become a reality.

Because of the close and dynamic interrelations between industry and technology, it is becoming increasingly apparent that technology should be considered in an integral manner with policies for industry, particularly industrial restructuring, as well as those for energy and human resource development. Technology will remain a key factor in development, and a suitable framework for national action to strengthen technological capabilities and expand the frontiers of international techno logical cooperation is imperative.

In the past, developing countries have been concerned mainly with whether, how and when to import existing technologies, and how to adapt them to local endowments. There has also been concern on how to hold at arms' length the powerful transnational corporations which are the main suppliers of technology, and on how to identify sources of appropriate technology. It is now equally important to evaluate the impact of new 'heartland' technologies on the world pattern of production and employment, and on the comparative advantage of developing countries in industrial production. Increasingly intense competition from low-cost, high-technology producers will necessitate special assistance for developing country industries if they are to achieve viability.

III. Trends in World Industry and Implications for Developing Countries' Technology

Manufacturing output and structural change

Between 1963 and 1980 the developing countries' share of world manufacturing rose (according to UNIDO) from 8.1 to 11 per cent. The annual growth of these countries' manufacturing averaged 8 per cent between 1963 and 1975, and 4.7 per cent between 1975 and 1982. At the same time, the slower growth in output of the industrial market-economy countries meant that their share of the total declined, especially in the case of the United States (the performance of Japan was dynamic throughout). Overall, there was a major transfer of industrial productive capacity away from the traditional suppliers of technology.

Among the developing countries the growth of manufacturing exceeded that of GDP. At the same time, there was a significant transformation in the structure of the manufacturing sector. The main factor in this transformation was the relatively faster growth in production of intermediate and capital goods (machinery, transport equipment, etc.) than of consumer goods: as a result, the share of the intermediate and capital goods sector increased from 48 per cent of the total in 1963 to 62 per cent in 1979. It was caused by a number of factors. They included the enlargement of markets and resource bases as a result of institutional and political developments and of a movement towards increased integration as industrial output increasingly formed linkages with the remainder of the domestic economy. This integration seemed to have occurred almost regardless of the orientation of industrialisation strategies, e.g. import substitution or export promotion. However, the effectiveness of the integration was not always clear.

Between 1963 and 1979 the fastest growing industry in developing countries was electrical machinery (annual growth of 11.4 per cent during 1963-73 and of 10.6 per cent during 1973-1979); and its share of industrial output more than doubled during this period. Production of chemicals, petroleum products, plastics, machinery, and metal products was also buoyant.

In developing countries, productivity growth was higher in heavy industries (especially metals and machinery) than in light industries,and this differential moderated the growth of employment. For example, between 1963 and 1980, the share of employment in the metals and machinery sector grew from 11.6 to 14.1 per cent of total employment in manufacturing, while the share of output grew from 15 to 24 per cent.

Expansion of the capital goods sector has been largely confined to newly industrialising countries (NICs). It has not expanded significantly among other developing countries and in some cases its proportion of industrial output has decreased. Trends in the capital goods sector are especially important as embodied technical progress originates largely within this sector. In no industry is this more true than of microelectronics which has often spearheaded technological innovation, both of products and of processes, as the industrial sector becomes more complex and forms greater linkages.

Microelectronics and development

The introduction of microelectronics has resulted in very rapid strides in product innovation. This bald statement can be variously illustrated. For example, in 1982 it was estimated that up to half the products manufactured in the West German electronics sector could not have been produced five years earlier Costs of semi-conductors declined and sales grew tenfold between 1970 and 1980. This, in turn, led to falling prices of computer equipment and made increasing use of computer controlled manufacturing processes, plant and equipment (including CAD, numerically controlled machine tools and industrial robots).

In its initial stages the electronics sector was boosted primarily by the demand for consumer goods - TV, radio, and high-fidelity recording and reproduction equipment. Such goods were particularly susceptible to relocation from the innovating centres towards sources of low cost labour as material costs fell and the ratio of labour costs to total costs increased. Simplification of manufacturing processes as these products became technologically mature lowered the ratio of skilled to unskilled labour and permitted employment of a relatively unskilled workforce, often female. Intense international competition forced transnational corporations to minimise costs by relocating their production between countries. As a result, the share of Asian developing countries in the production of these goods, which had been negligible in 1966, had by 1979 reached 16 per cent for TV production and 19 per cent for sound recorders.

The extent to which the developing countries which have attracted foreign investment are able to sustain independent technological development depends largely on the degree of transnational corporation control over production and R&D. Currently, only Taiwan and South Korea appear to have been able to move away from dependence on TNC subcontracting, whereas production of electronics goods in countries such as Malaysia, Singapore, Thailand and Philippines has remained predominantly under TNC control. Firms such as Samsung (Korea) and Tatung (Taiwan), which have successfully opened subsidiaries in the UK and USA to produce consumer electronic components and products, require independent control and considerable facilities for technological R&D and distribution. Progress outside the Asian NICs has been slow, but a number of other developing countries, including India and Mexico, have embarked upon relatively ambitious programmes.

Implications of microelectronics development for the Third World

The emergence of some NICs as major producers of high-technology products has ambiguous implications for other developing countries. On the one hand, these countries provide a model for a form of industrialisation which has had a marked success in creating full employment and raising living standards. On the other hand, it could be argued that because technological gaps are widening, export markets have been preempted, and capital and skilled labour resources are increasingly concentrated, the emergence of these countries has made the prospects for late starters even less promising. But even within these Asian NICs it is not yet clear whether the growth of electronics (and other branches of engineering) will be sustained by independent control, or whether it will be subject to the production, marketing and investment decisions of transnational corporations.

The last question can, in fact, be applied to the engineering sector as a whole. For many developing countries 'engineering' still consists of only a few stages of manufacture, usually including the final stage of assembly. This is in contrast to a mature industry with an integrated structure and different stages of production in close touch with each other, which has been shown to be critical to the technological innovation process. The production of a component, or assembly of a piece of equipment, by relatively unskilled labour working for the subsidiary of a transnational corporation will not of itself give rise to the necessary learning in terms of innovative product or process design. Assistance to support and strengthen initiatives in fledgling engineering industries is of paramount importance. Such assistance may include efforts to attract technology and investments from commercial sources in other countries, both developed and developing, and technical support to the small engineering workshops where new ideas often emerge. If innovation and competitiveness are to be stimulated in Commonwealth developing countries, it is necessary that these countries develop a capacity in the area not only of electronics but of engineering generally.

IV. IDU Assistance in High-technology Industrialisation: Three Cases

It has often been stressed (e.g. at UNIDO IV) that high-technology options should be a part of the appropriate technology structure of developing countries. These options, which include the application of microelectronics in industry, have been reflected in assistance given by the IDU in several projects. Three of these projects are summarised below.

CAD/CAM assistance for automotive industry (India)

At the request of the Government of India, IDU is assisting the Automotive Research Association in Poona to set up an advanced technology research and design facility for the Indian automotive industry. IDU responded to the request by designing a project with the following key characteristics. First, the transfer of CAD/CAM know-how to design engineers in the Automotive Research Association of India and the automotive manufacturing companies.

In addition to training these engineers in relevant CAD/CAM techniques, analysis was undertaken of components like the crankshaft, motor chassis, bend gear, axle shaft and engine piston so that tangible benefits could be shown to the participants and the results used in producing these components. Secondly, a telecommunications link was established between computer terminals at the Research Centre in Poona, and an international network in the UK, Belgium and the USA. This link not only delivered the necessary computing power to the Centre but established the technical feasibility of linking developing countries to international networks. This type of networking will play an increasingly important role in information dissemination among developing countries. Thirdly, the practical needs of the automotive industry were assessed and suitable hardware and software identified. Finally, an action plan was developed to assist in setting up a CAD/CAM facility in India. When implemented, the project should allow India to develop advanced technology of a high effectiveness.

Development of electronics industry (Trinidad & Tobago)

As part of its strategy to diversify the country's economic base and to benefit from the Caribbean Basin Initiative, the Government of Trinidad and Tobago decided to accord high priority to the establishment of an electronics sector. It requested the IDU to assist in identifying areas in the manufacture of electronic components and electronic goods that offered the best economic prospects for viable operation in Trinidad and Tobago.

In-house work by the IDU soon revealed that what was needed first was the formulation of a realistic strategy for successful development of this sector, bearing in mind the strengths and weaknesses of the project environment. Trinidad and Tobago has a strong technical base, including the University of the West Indies Engineering Department and two other technical institutes. The Caribbean Industrial Research Institute (CARIRI) has a strong application-oriented electronics department. Initial field-work was undertaken by IDU staff and after discussions with the project authority, the Caribbean Basin Business Centre in Washington, it was agreed with the Government of Trinidad and Tobago that a structured approach would be taken, with a strategy formulation followed by a product identification.

As this project represents the first major initiative undertaken by the Government of Trinidad and Tobago in the development of a high-technology industry, it is vital that the policy formulated be not only innovative but practical. The project seeks to develop specific initiatives and catalytic-actions that the authority and the Government need to take to attract investment from high-technology US companies and to create indigenous manufacturers of electronic goods. Extensive fieldwork is to be undertaken in the USA to assist the Government of Trinidad and Tobago in understanding the locational and other requirements of US companies for setting up a manufacturing unit. This, in turn, would assist in preparing a package to attract US high-technology companies to Trinidad and Tobago. After helping to formulate an implementable strategy, the IDU will identify product areas that offer the greatest scope for domestic manufacture.

Development of electronics industry (Malaysia)

There are in Malaysia many transnational corporations operating in the electronics sector. But if the indigenous technology of the country is to develop in this sector, it is important that mechanisms are created to encourage the diffusion of such technology into a variety of productive enterprises, especially into small-scale units. IDU studied the key sectors of electronics, electrical and metal-working industries in Malaysia, and formulated a strategy for the development of small-scale units in these sectors. In addition it identified several items that could be successfully manufactured in small-scale units, and prepared feasibility reports, including action plans and project profiles, for those items that appeared to be most attractive for immediate production.

CHAPTER VI

BIOTECHNOLOGY AND THE THIRD WORLD

R.N. Azad

Food Production and Rural Development Division,
Commonwealth Secretariat,
London.

October 1984

This paper was written when the author was on the staff of the Commonwealth Secretariat. The views expressed are, however, personal and do not necessarily reflect those of the Commonwealth Secretariat.

BIOTECHNOLOGY AND THE THIRD WORLD

Contents

BIOTECHNOLOGY AND THE THIRD WORLD

This paper seeks to present briefly major developments in biotechnology. It outlines areas in new and traditional or conventional biotechnology which appear to be of greatest relevance and feasibility or are likely to have much impact on developing countries, and focuses on some aspects which should receive the attention of these countries.

Definitions and Developments

Biotechnology is multidisciplinary in nature and its full potential is yet to be realised. There is no universally accepted definition of the subject and at this stage of its development this is not surprising. As a result of rapid developments in this expanding field and the interest they have created, governments, organisations and individuals have given diverse definitions of biotechnology (Appendix I,page 400). Some definitions exclude medical technology, agriculture and traditional crop breeding, but the two most commonly used are of wider scope, viz: (i) "the application of scientific and engineering principles to the processing of materials by biological agents to provide goods and services" (OECD study by Bull *et al*, 1982); and (ii) "Biotechnology, broadly defined, includes any technique that uses living organisms (or parts of organisms) to develop micro-organisms for specific uses" (OTA report, anon., 1984).

As the focus of this paper is on the relevance of biotechnology to the Third World, and because some aspects of traditional or conventional biotechnology will continue to be of great importance for the economic and social development of these countries, this type of biotechnology is included in a working definition of the term, although it is separated from the 'new' biotechnology which the author calls 'high-tech biotechnology'.

Traditional or conventional biotechnology includes those technologies involved in the development of: fermentation for alcoholic drinks and for foods (numerous examples exist of commonly used and sometimes highly nutritious foods, in both industrial and developing countries); plant and animal breeding (since the classic work of Mendel at the end of the 19th century); sera and vaccines; pasteurisation and sterilization of foods (including the more recent long shelf-life foods and irradiated foods yet to be cleared for human consumption) since the discoveries of Louis Pasteur in the later half of the 19th century; artificial insemination of cattle; artificial propagation of fish by induced spawning through stripping, hormone injection (hypophysation) of pituitary extracts derived from fish, mammalian and synthetic sources (developed in India and China in the late 1950s for carp but now used for tilapia, catfish, trout, mullet, shrimps etc); inoculation with Rhizobium cultures to enhance legume yields (first applied in 1895 in Germany and in 1924 in UK); biological control of crop pests; use of algae as fertiliser; antibiotics (since Fleming's work of 1929 on penicillin); biogas, etc.

The 'new' or high-tech biotechnology is a term usually restricted to practical applications of recent advances in protein and nucleic acid chemistry, molecular genetics and recombinant DNA technology. It is, in fact, the most recent phase in a historical continuum of the use of biological organisms for practical purposes. Developments arising from these new technologies are spawning others which can make even the potentially most useful current technology obsolete in a short time. The OTA report has thus emphasised that any definition of biotechnology will involve an assessment of developments at a particular point in time.

The preceeding paragraphs have given some milestones in the development of traditional biotechnology. The series of dynamic recent advances, of far reaching consequences, in high-tech biotechnology can be ascribed to the discovery of the chemical structure of DNA by Watson and Crick in 1953. The most important developments in the commercialisation of biotechnology which have taken place in the last decade are given in Table 1 (page 371). Rapid advances are continuing: the fact that the 1984 Nobel Prize for Science was awarded to Neils Jerne, Georges Koehler and Cesar Millstein for their work on monoclonal antibodies illustrates this point.

Areas of Potential Application

Bull *et al* (1982) have summarised present applications of biotechnology in various sectors (Appendix II, page 402) and given examples of applications of genetic manipulation (Appendix III, page 403). Notes on major applications are given below (source: Commonwealth Mycological Institute *et al*), though what follows is not an exhaustive list.

(a) Food and agriculture

A wide area, encompassing traditional and modern fermentation technology, viz., brewing, fermented solid and liquid foods, new products such as polysaccharides and protein-enhanced foods, and enzyme engineering used for the catalysis of specific chemical reactions to produce a range of products including amino-acids and high fructose syrups. Both fermentation and enzyme engineering processes have much wider applications than foods, such as the production of antibiotics and drugs. The creation of single cell proteins using widely available substrates (usually petrochemicals such as gas oil and methane) and micro-organisms (especially *Fusarium*) has aroused much interest for the production of both human food and animal feed, although the immediate

Table 1

MAJOR EVENTS IN THE COMMERCIALIZATION OF BIOTECHNOLOGY

1973	First gene cloned
1974	First expression of a gene cloned from a different species in bacteria. Recombinant DNA (rDNA) experiments first discussed in a public forum (Gordon Conference).
1975	U.S. guidelines for rDNA research outlined (Asilomar Conference). First hybridoma created.
1976	First firm to exploit rDNA technology founded in the United States (Genentech). Genetic Manipulation Advisory Group (U.K.) started in the United Kingdom.
1980	Diamond v. Chakrabarty - U.S. Supreme Court rules that micro-organisms can be patented under existing law. Cohen/Boyer patent issued on the technique for the construction of rDNA. United Kingdom targets biotechnology (Spinks' report). Federal Republic of Germany targets biotechnology (Leistungsplan). Initial public offering by Genentech sets Wall Street record for fastest price per share increase ($35 to $89 in 20 minutes).
1981	First monoclonal antibody diagnostic kits approved for use in the United States. First automated gene synthesizer marketed. Japan targets biotechnology (Ministry of International Trade and Technology declares 1981 "The Year of Biotechnology"). France targets biotechnology (Pelissolo report). Hoescht/Massachusetts General Hospital agreement. Initial public offering by Cetus sets Wall Street record for the largest amount of money raised in an initial public offering ($125 million). Industrial Biotechnology Association founded. DuPont commits $120 million for life sciences R&D. Over 80 NBFs had been formed by the end of the year.
1982	First rDNA animal vaccine (for colibacillosis) approved for use in Europe. First rDNA pharmaceutical product (human insulin) approved for use in the United States and the United Kingdom. First R&D limited partnership formed for the funding of clinical trials.
1983	First plant gene expressed in a plant of a different species. £500 million raised in U.S. Public markets by NBFs.

Source: Office of Technology Assessment, U.S.A.

economic viability of such processes is open to question and may depend on future waste treatment legislation.

Biotechnology has a direct involvement in crop production. The energy crisis stimulated the development of nitrogen-fixing organisms, especially Rhizobium strains, to increase soil fertility and lessen the need for chemical fertilisers. It also opened the possibility of using genetic engineering to develop crop plants which produce their own nitrogen.

Another area of development concerns the control of crop pests using biological agents, mainly the use of micro-organisms and predatory insects against insect pests. Suitable organisms, perhaps in future genetically engineered and produced in commercial quantities, will give a more efficient and selective alternative to pesticides. High-yielding or disease resistant qualities may also be built into crops by genetic engineering techniques.

Technology for producing animal feed differs from that for human food,in that the degree of conversion of the starting materials need not be so great, and the legislation regarding safety, testing and preservation tends to be less stringent. Many low-tech processes have significance here. One example is the solid state fermentation of straw (composting) under non sterile conditions using selected fungi to produce an up-graded feed equivalent to hay. This has been used in a pilot factory in Canada but the economics of using the process on a large-scale is still uncertain. The substrate used in such conversions is often considered as waste.

(b) Waste recycling and pollution control

This has a long history, which is now taking on greater significance as the need to conserve resources grows. The range of potential substrates is wide, as they can come from:

agriculture - plant stems (straw), bagasse, maize cobs, bean and nut hulls, fruit peelings, oilseed pressing wastes, bran, fruit pulp, animal feedlot wastes;

forestry - wood waste, sulphite pulp liquor, bark, sawdust, paper and fibre waste;

industry - food wastes (olive, potato, citrus fruits, cassava, palm oil,waste waters (dairies, canneries), meat and fish effluents and wastes, whey), distillery wastes, molasses and other wastes from sugar refineries; and

sewage and municipal garbage - some of which pose serious pollution and health problems, giving an extra incentive to usefully process them.

The detoxification of chemical wastes and spills is another area which has aroused interest, although applications are not well developed. Much interest has centred upon the use of micro-organisms in cleaning oil spills, both in marine and terrestrial environments.

There are various approaches for the utilisation of such wastes:

selective direct use, e.g. for fuel, building materials, extraction of further useful chemicals;

biogas (methane) - production for use as fuel now extensive in many parts of India and China;

feeding - to animals, especially ruminants, whose multiple stomachs can deal with very high fibre contents. Processing the waste may render it suitable for use by animals such as fish, pigs or poultry; and

upgrading - for use as human food.

(c) Alternative energy sources

The production of cheap liquid and gaseous fuels is a goal which has already stimulated the development of a wide range of methods. Ethanol production as an alternative to petroleum spirit (e.g. from sugar cane in Brazil, oil palm in Malaysia, and molasses in India), and methane (biogas) production from animal wastes are examples. Other chemical fuels are possible using substrates such as milk solids, sugars and cellulose from food processing and agriculture, using specially developed organisms.

(d) Chemicals

Some products are traditional and supplies may be enhanced by consideration of locally available alternative products, e.g. industrial ethanol from molasses (used on a large scale in India for synthetic rubber production), acetic acid, butanol and acetone (especially in countries short of petroleum); alternatively they may be protected by consumer safety or legislative considerations, e.g. beers, wines, vinegar and citric acid.

New processes have grown up, e.g. amino acids and nucleotides (especially in Japan). Microbial polysaccharide production is another growth area.

As genetic engineering develops, the field of chemical production is expected to expand greatly.

(e) Medical and veterinary care

Many important therapeutic agents are produced by biotechnology. The best known are the antibiotics produced from fungi. New processes include the production of insulin and interferon, the latter having potential importance in the treatment of viral diseases and perhaps cancers. Vaccine production, now assisted by the use of monoclonal antibodies, is another example of the application of biotechnology to the medical and veterinary field.

Economic and Social Aspects of Biotechnology

As a result of the rapid technological advances and the actions being taken by governments, universities, research institutions and commercial companies, biotechnology is having increasingly significant economic, social and environmental impacts. As an indication of this trend, Elkington (1983) identified 830 organisations involved in biotechnology in the health field alone. Their geographical and institutional breakdown is given in Table 2 below.

Table 2

BIOTECHNOLOGY ORGANISATIONS IN HEALTH-CARE

(source: IMS World)

Region	Academic institutions	Corporations	Specialist companies	Total
Europe & Israel	162	106	32	300
USA, Canada & Mexico	137	111	146	394
Japan, Asia & Australasia	51	83	2	136
Total*	350	300	180	830

* Sample of 27 countries.

From: Elkington, J.,"Biotechnology and Employment: The Integration of Traditional Economic Activities"; Case Study prepared for the ILO, October, 1983.

Some aspects of these impacts and their implications for the Third World are briefly examined below.

Economic aspects

(a) Investment

On a national level in countries developing biotechnology, there is usually initial government help, both in funding and in coordination. The level and type of support varies, as is evident from the following (source: CMI and others):

Australia - interest on a wide front, including high-tech areas. A review for the CSIRO was prepared in 1981;
West Germany - has a central biotechnology institute and a high level of government support;
USA - has tended to attract a higher level of venture capital than other countries. The U.S. Department of Agriculture has a £2 million programme to develop plants for use as feedstock for ethanol production;
France - works via government agencies, particularly in the fields of energy and feedstuff production and waste treatment;
Japan - active support of research directly by government and also within major companies;
Brazil - has a large fuel alcohol production programme;
UK - increasing support in a variety of ways. £10 million governmental funding of projects via British Technology Group;
India - has set up National Biotechnology Board which oversees developments and sponsors and coordinates R & D in biotechnology. Research is also carried out by CSIR's Institute of Industrial Microbiology and in relevant national institutes (e.g. Indian Agricultural Research Institute, Central Food Technological Research Institute, Biotechnology Centres in National Dairy Research Institute and Indian Veterinary Research Institute, etc); and
Malaysia - had spent some M$10 million by mid-1983 on clonal oil

palm R & D and recently succeeded in producing motor spirit from oil palm.

Precise figures of investment in biotechnology are not available. According to Fishlock (1984), the US companies are spending some $2 billion (about $500 million by 'new biotechnology firms' and $1,500 million by older established companies); Japan appears to be the next largest investor, though it was only in 1980 that it started to invest on a large scale in response to what was seen as a threat to its pharmaceutical industry; in Western Europe, Switzerland seems to be the leader.

The incentive to invest in biotechnology can be judged from the fact that a new chemical pesticide could cost £12 million to develop and would need a £30 million annual market to recoup that investment, whereas a bioagent might be developed for £400,000 and could make a profit from £600,000 annual sales. This is besides the technical superiority of bioagents over chemical pesticides, there being no known problems of environment or of pests developing resistance (Fishlock, 1984).

Even so, the levels of investment required for R & D in biotechnology are not at present within the means of most developing countries, although the more industrially advanced among them could take up selected products requiring comparatively small investment and for which they had the required 'raw material'. Table 3 (page 378) categorises biotechnology products according to technological and investment levels.

Table 3

BIOTECHNOLOGY: BASED ON TECHNOLOGICAL AND INVESTMENT LEVELS

Category	Products
High level: High capital investment; sophisticated plant and processes often requiring strict containment; high maintenance costs; high operator skills.	High value-added products and products destined for health care and human food and food additives. Large-scale continuous processes.
Intermediate level: Moderate capital investment and less complex operations	Fermented foods and beverages. Animal feedstuffs. Biofertilizers and pesticides. Crude enzymes. Waste management processes which entail sophisticated operation and control.
Low level: Small capital investment and scale of operation; simple and usually indigenous equipment; labour-intensive operations; open septic systems; village level technology.	Low level products frequently related to alleviation of pollution, sanitation, fuel and food provision. Extensive use of naturally adopted mixed fermentations. Biogas; microbial protein from agricultural and food wastes; traditional fermented foods and beverages; mushroom production.

From: Bull et al, Biotechnology: International Trends and Perspectives; OECD Paris, 1982.

(b) Production

Statistics of production of biotechnology-related industries in selected OECD countries as percentages of their GDP are given in Table 4 (page 379). Similar information for other countries was not available. But the importance of biotechnology in developing countries can be illustrated with an example from

Table 4

STATISTICS FOR BIOTECHNOLOGICALLY-RELATED INDUSTRIES

Some Comparative Production Statistics (1978)

Country	Food[a]	Chemical Products[b]	Drugs Medicines[c]
	Production value as % of GDP		
France	10.5	12.8	n.a.
Germany	7.4	15.1	1.1
Japan	8.9	14.9	1.4
New Zealand[d]	15.5	6.0	0.3
Norway	13.2	8.8	0.2
Sweden	7.9	7.1	0.5
United Kingdom	9.8	14.8	1.0
U.S.A.[d]	9.1	13.6	0.8

a) b) c) According to ISIC classifications 311/2, 3500 and 3522 respectively.

d) Data for 1977

Source: OECD

From: Bull *et al*, Biotechnology: International Trends and Perspectives, OECD, Paris, 1982.

Brazil, which by 1985 was expecting to produce 10.7 billion litres of alcohol (ethanol) and 250,000 cars with engines designed to use ethanol.

Far reaching changes in input:output ratios and in product quality can result from high-tech biotechnology. For example, ICI's single cell protein animal feed supplement, 'Pruteen', is produced from natural gas, via methanol, and exploits a resource which is often wastefully flared over the world's oilfields; ICI sees the technology's advantages as including its complete independence of the weather and the fact that it requires only 100 hectares to produce one million tonnes of 'Pruteen' compared with two million hectares to produce soya bean meal of the equivalent protein. By the end of 1982, about 50,000 tonnes of Pruteen had been sold to manufacturers of livestock feed in several countries and 120 million animals of various species had been successfully fed on 'Pruteen'-containing diets. ICI was extending its 'Pruteen' programme by entering into collaborative ventures in the USSR, OAPEC and other countries. One product similar to 'Pruteen' is Phillips Petroleum's 'Provesteen', which uses yeast and may be able to exploit a wider range of feedstock like ethanol, methanol, glucose, sucrose and agricultural and forestry wastes, which are important for poorly endowed countries (Elkington, 1983). Another example is clonal oil palm: Unifield produced 100,000 plants in 1983 and had a target of one million plants a year. In the early 1980s, clonal plantlets cost £2.50, compared with perhaps some 14p for oil palms grown from seed, but the rapid improvements in cloning technology and the considerably boosted yields from clonal palms suggest that the new technology should soon become competitive.

Biotechnology is also entering the human food sector. One category of products of high-tech biotechnology important in the food industry are enzymes. The world market for industrial enzymes, which includes those used in the food sector, was put in

1981 at around 65,000 tonnes valued at $400 million, with likely growth to 75,000 tonnes and $600 million by 1985. The most famous enzymes in the food sector are the sweeteners such as fructose (aspartame) which is chemically synthesised from the amino acid asparatric acid and phenylalamine and manufactured bio-synthetically via fermentation. It is 200 times sweeter than sugar and safer than the artificial sweeteners saccharine and cyclamates which were found to cause cancer in animals in laboratory tests. Nevertheless, aspartame still has some problems for people suffering from an inherited inability to metabolise the amino acid and is alleged to be capable of causing mental disorders (though the product has been cleared by the UK health authorities).

Another category are biotechnology products which are of direct use in human food. One example is mycoprotein, a microfungus of the mushroom and truffle genus, which has been grown by the British company RHM under vigorously controlled conditions in a continuous fermentation process upgrading carbohydrates into high quality protein; RHM is using glucose syrup made from starch feedstock, a variety of indigenous carbohydrates like corn, rice, cassava, molasses and many residue wastes of the food industry. Mycoprotein is a natural organism unmodified by genetic engineering - a step the food industry is reluctant to take; its thread-like shape confers valuable textural properties for making simulated foods, including some resembling meats such as chicken and veal; it is the equivalent of milk protein, low in fat and sodium, high in fibre and with no cholesterol - all the factors demanded by the modern nutritional establishment (Fishlock, 1984 and Elkington, 1983). RHM's Director of Research informed the author that mycoprotein was comparatively expensive and the immediate market would be in the more affluent societies. The product was formally cleared by the UK Government in 1980 as safe for human consumption. When production costs have been markedly reduced, one can see considerable potential uses for the product in some Third World countries facing acute malnutrition and protein deficiency and at the same time having abundant, even surplus, supplies of starch.

A second example is of a product which has been developed by Bio-Isolates (of Swansea, Wales) from the whey effluent of creameries. This otherwise goes to waste and poses disposal problems (South Caernarvon Creameries typically produces some 20 - 22 million litres of whey a year). The process involves a hydrophilic ion exchange technique for isolating the protein in commercial quantities; the product, which is a powder, contains 97 per cent protein, 3 per cent minerals and mere traces of fats and lactose (Elkington, 1983).

(c) Employment

It is too early to assess the employment effects of high-tech biotechnology in developing countries; however, it can safely be asserted that its direct adoption or use of its products should not result in any significant loss of employment in developing countries. Indeed the experience of introducing the high yielding varieties (HYV) and the accompanying agricultural mechanisation which resulted in the 'green revolution' of the mid-sixties disproved earlier fears that it would cause unemployment. In the Indian Punjab, where the HYV programme has been a major success, the higher production has resulted in greater labour absorptive capacity in the primary, secondary and tertiary sectors: the Punjab is now importing manual labour from other states of India.

Watanabe (1984) and Elkington (1983) studied several aspects of biotechnology as it related to employment. Watanabe's study on the employment implications for Africa was almost entirely focused on the achievements of traditional biotechnology, mainly plant breeding. It cited two interesting examples: (i) the replacement of bananas by oil palms in Costa Rica,which caused unemployment till such time that the oil palm expansion had created sufficient new employment in the secondary and teritiary sectors; and (ii) the genetic improvements resulting in the shifting of native crops of Africa to other countries, e.g. oil palm (a native of West Africa) from Nigeria to Malaysia. Elkington studied the employment implications of traditional oil palm versus clonal oil palm, and found that Unilever employs 3,200 people in the plantations (13,000 hectares) and 40-50 people in the processing mills. More significant for employment has been the use of the weevil *Elaeidobius Kamerunicus* to replace manual pollination of oil palm. The workers thus freed were redeployed around the plantations and though the labour intake was affected, that should only be temporary as the 30 per cent increase in the oil yield per hectare of clonal plantation than of uncloned one should result in additional employment. Overall, there seems to be no cause to fear for employment as a result of the introduction of biotechnology in the Third World. In fact, when the present agricultural,forestry and industrial wastes are exploited to produce a variety of goods of higher value and multi-use, the use of biotechnology should create new employment.

The developing countries pursuing biotechnology will create a new demand for semi-skilled and highly professional people, qualified and trained in various disciplines such as biochemistry, chemistry, microbiology, engineering (chemical and other branches), genetics, immunology, human and animal nutrition, food technology, physiology etc. Therefore, the developing countries deciding to enter into high-tech biotechnology will first need to assess their human resources and, if they are to acquire self-sufficiency, take up well designed, pre-planned programmes of human resource development.

(d) Trade

Market forecasts for some biotechnology products, their value in various sectors, and their contribution to trade have been studied by Bull *et al* (1982) and Elkington (1983). Appendix IV (page 405) gives some biotechnology market forecasts, Appendix V (page 407) some market predictions for genetic engineering products, and Appendix VI (page 409) some estimates of the value of applied genetics and new biotechnologies in various sectors of the US market. Information on trade in biotechnology products is not available and even that on medicinal and pharmaceutical products is confined mostly to OECD countries.

It is thus impossible to assess the impact of biotechnology on the trade of Third World countries. However, the implications of some possible future developments can be foreseen. The proteins successfully developed for additives to cattle feed could in the long run affect the exports of concentrated cattle feed such as oil cakes, rice bran etc. from the developing countries. New sweeteners have already reduced, and might in the long run almost eliminate, the demand for sugar exported by developing countries. Likewise, synthetic rubber, which has already replaced natural rubber in many industries, might complete the process. There are doubtless other examples and there will be more, perhaps of products which are major sources of foreign exchange earnings. However, the countries concerned need not be adversely affected provided they foresee and plan for such eventualities. In fact, the diminishing foreign demand for these traditional items could be the development which causes the countries to pursue more advantageous alternatives. For example, oil cakes and rice bran could be used to build indigenous livestock and dairy industries (in India the poultry industry has been affected by rice bran exports); the rubber plantations could be gradually replaced by more remunerative oil palm,as in Malaysia. And to maintain foreign exchange earnings the affected countries could produce for export products from a few selected lines of high-tech biotechnology, which would use as feedstock the countries' most abundant industrial or agricultural wastes or raw materials.

Social aspects

Recent advances in biotechnology have raised some questions in regard to health, security, ethics and the environment. These issues are all the more important for the Third World because the industrialised societies which have developed the use of high-tech biotechnology are well aware of the implications and have been taking the necessary precautionary measures.

(a) Health

Antibiotics (a word first used by Waksman in 1945) produced from fungi have played an important and growing role in the treatment of human and animal diseases since the 1940s. The applications of high-tech biotechnology to pharmaceuticals, i.e. in relation to human and animal health, are being pursued at present through the production of proteins such as insulin, interferon and human serum albumin; antibiotics; MAB diagnostics; and vaccines for viral, bacterial and parasitic diseases. Interferon is particularly promising and has already shown potential for the treatment of viral diseases and possibly cancer. As more is learned about hormone growth factors, immune regulators and neurological peptides, their efficacy in the treatment of disease may increase dramatically.

Another important area in which high-tech biotechnology has shown promise is early diagnosis of diseases through specific tests. At present the physician is handicapped by having no specific tests for many human conditions from hepatitis B to AIDS, and for others like cancers, there is in many cases no easy way to early detection. Therefore, many new biotechnology firms have included diagnostics in their corporate plans. Much has already been achieved with monoclonal antibodies in pregnancy tests, predicting human ovulation, animal breeding, and identification of plant viruses (Fishlock, 1984).

(b) Security

In the early 1970s, when the technology of genetic manipulation was acquired and it became known that it was capable of creating new forms of life, a widespread apprehension was expressed by the public, as well as by some scientists, towards genetic engineering. Successful cloning of foreign genes in the bacterium Escherichia coli, which inhabits the alimentary tract and sometimes infects the kidneys and urinary tract, initially caused much apprehension regarding safety risks. However, subsequent developments, together with the precautionary and regulatory measures taken, have allayed much of that apprehension, and presently there seems no justification for alarm in regard to genetic engineering unless the technology is allowed to make inroads into human genetics (in ways different from artificial insemination and embryo transplants etc., which are of proven value, though about which religious and ethical views differ).

On the other hand, the pathogenic micro-organisms, in contrast to the conjectural hazards of rDNA technology, do present real risks. Surprisingly these did not cause so much concern regarding handling in new biotechnological processes.

In sum, public safety must be of prime concern in designing and operating technologies and handling the various agents, including organisms, employed in them. The OECD report (Bull et al, 1982) emphasized that all countries should have regulations concerned, on the one hand, with health and safety at work, and on the other, with protection of the public and the environment. Unification of standards for good laboratory practice and manufacturing procedures should be encouraged internationally. At a time when humanity is very concerned at the hazards of atomic weaponry, international controls at the early stages of biotechnology, especially genetic engineering, become all the more necessary as a safeguard against the production and stockpiling of the lethal biological weapons of war.

(c) Ethics

Some ethical aspects of biotechnology have already been touched in the foregoing. In the Symposium on Genetic Engineering of Plants, held in 1983 in Davis, California, an interesting ethical question was raised on the commercialisation of biotechnology (Simmonds, 1983). The trend towards the involvement of industrial conglomerate companies in plant breeding and related areas of biotechnology, including genetic engineering, was clear in the USA and likely to extend to other industrialised countries. The extension of plant breeding to private companies should in general be welcomed. However, care was required against certain hazards of private industrial involvement, e.g. the distortion of breeding objectives to satisfy other commercial objectives such as sales of agro-chemicals.

Similar questions of commercial ethics arise in promoting sales of biotechnology products by transnationals and other commercial companies, especially in the Third World. It is well known that products whose use has been banned in the countries of origin, continue to be consigned to the developing countries. Prominent among them are pesticides and, despite the strong stand taken by the WHO, baby foods, together with multivites and various tonic preparations of doubtful benefit which have no market in the industrialised countries. It is also common knowledge that many drugs, especially antibiotics, have long been sold by transnationals in poor countries at prices which bear no relation to their manufacturing cost and are higher than those charged in the (industrialised) countries of their manufacture. Some regulatory measures are necessary against such unethical commercial practices. Third World countries, moreover, should not be allowed to become the testing ground for new products of doubtful safety. As the application of biotechnology expands, new ethical issues will doubtless arise. These will need constant vigil by governments and public bodies.

(d) Environment

The applications of biotechnology which have environmental implications include mineral leaching and metal concentration, production of degradable plastics, treatment of sewage and municipal garbage, control of pollution, degradation of toxic waste, and enhanced recovery of oil. Such applications may take longer to reach the market for large scale usage. However, regulations and safeguards will be necessary because these applications use micro-organisms that are deliberately released into the environment. There may also be risk of disturbing the balance of nature or the eco-system in certain cases and care will have to be taken to avoid such an eventuality.

Biotechnology in Developing Countries: the Potential and Some Policy Issues

The applications of biotechnology have opened new potentials for developing countries in their quest to alleviate food shortages, to supplement energy supplies, to treat human and animal diseases, to produce a wider range of goods and services, and thus generally to achieve higher economic growth and an improved quality of life. The potential is such that developing countries cannot afford to be second or third in certain aspects of biotechnology (Hartley, 1984).

Traditional biotechnology

This will continue to be crucial for the Third World (as for the industrialised countries), especially for those countries which have not yet fully benefited from the developments in plant and livestock breeding, in the use of *Rhizobium* cultures for enhancing legume yields, in techniques for post harvest loss reduction, biogas and ethanol production, etc. The same is true for other technologies of proven value, e.g. tissue culture used to produce virus-free seed potatoes since the early 1950s (Vasudeva and Azad, 1950) but subsequently much further developed and refined (Simmonds, 1983), and the artificial propagation of fish, whose benefits are yet to reach many developing countries.

According to the FAO, by the early 1980s 55 countries in the Third World, with more than a billion inhabitants, were no longer able to feed themselves adequately using traditional methods of agriculture; in almost two-thirds of these countries, livestock was lost because of disease and inadequate management techniques; some 225 million people were under-fed in Africa alone, where 22 countries were facing acute food shortages and in some cases famine; the destruction of the environment was continuing inexorably and the deserts were spreading in Africa and elsewhere. To meet these major problems, the traditional biotechnology has much to offer.

The high-yielding varieties programmes introduced in the mid 1960s ushered in the 'green revolution' in many parts of the developing world, especially South and South-east Asia. For instance, in India food production increased from about 52 million tonnes in 1950 to 152 million tonnes in 1983-84, and milk production went up from 17.4 million litres in 1951 to 32.9 million litres in 1982; this was achieved through breeding as well as by better management practices, and led to improved nutrition and health.

The continuing importance of traditional biotechnology has been emphasised by many writers. For example, Borlaug (1983) asserted that "since it is doubtful that significant production benefits will soon be forthcoming from the use of genetic engineering techniques with higher plants, especially polyploid species, most research funds in crop improvement should continue to be allocated for conventional plant breeding". Similar sentiments were expressed by the Rockefeller Conference on Genetic Engineering for Crop Improvement (Anon., 1981).

What is needed in Africa is the adaptation of dry-land farming techniques and drought resistant crop varieties to local conditions, an intensification of the search for new varieties, more emphasis on agro-forestry, the exploitation of all possible irrigation resources, the organisation of location-specific R&D and the development of the necessary infrastructure and management techniques for agriculture. Many traditional crops of great importance to Africa, the Caribbean and the South Pacific islands have been receiving too little attention by research scientists and extension workers. This has been true of cassava, aroids, sweet potato, cooking bananas, grain legumes (except for a few species such as pigeon pea), drought resistant crops like finger millet (Eleusine corracana), and traditional foods such as pandanus, taro, and bread fruit.

Another area needing attention is the improvement of existing biotechnologies used extensively in developing countries for fermentation, brewing etc. in order to raise the quantity and quality of output. For instance, fermentation processes are widely used in Africa for producing alcoholic beverages (palm wine, pito from sorghum and maize, buro kuto beer from sorghum and gari) and non-alcoholic fermented foods, e.g., gari from cassava, ogi from maize and millets, vinegar, and soy-ogi - an infant weaning complete protein food recently developed in Nigeria (Ekundayo, 1980). It is highly desirable that the fermentation processes for making these products are improved.

Conservation of genetic resources

Some estimates suggest that tree formations are being lost at the rate of 11 million hectares every year. For every 10 hectares of forest lost, barely one hectare is being replanted in tropical America, Africa and Asia. This has serious implications, not only for the integrity of the environment and the eco-system but also for the preservation of genetic variability, especially when it is recalled that the variety of flora and fauna is much greater in the tropics than elsewhere. Some estimates indicate that so far only one in six tropical plants and animals has been given a scientific name (Swaminathan, 1983 a). Of an estimated 30 million species of living organisms on earth, only 250,000 are plants; of a global total of 80,000 species of edible plant, only about 150 have ever been cultivated on a large scale, and 90 per cent of the world's food is produced from less than 20 species. Many examples exist of under-exploited plant species with proven potential in food, medicine and industry (source: CSC). Hence, it is not even known what is being lost by the destruction of forest canopies, apart from the creation of recurrent droughts and increasing desertification.

High-tech biotechnology

The Third World has long since contributed essential raw materials for the industrial development of the 'North'. Likewise, developing countries have potential raw material resources for new biotechnological products which would be of interest to both the 'North' and the 'South'. Some of these raw materials are listed in Table 5 below. In using them, however, developing

Table 5

TYPICAL BY-PRODUCT SUBSTRATES FOR USE IN MICROBIAL PROCESSES IN DEVELOPING COUNTRIES

Agricultural	Other
Molasses	Animal Manures
Maize Stover	Sewage
Straw	Municipal Garbage
Bran	Paper Mill Effluent
Coffee Hulls	Cannery Effluent
Cocoa Hulls	Fishery Effluent
Coconut Hulls	Slaughterhouse Effluent
Fruit Peels	Milk-Processing Effluent
Fruit Leaves	
Bagasse	
Oilseed Cakes	
Cotton Wastes	
Tea Wastes	
Bark	
Sawdust	

Source: Anonymous, 1979, Microbial Processes: Promising Technologies for Developing Countries, National Academy of Sciences, Washington, D.C.

countries will have to be vigilant that they do not once again become victims of exploitation by nations which are already rich.

The exploitation as biotechnology feedstock of raw materials possessed by the Third World could take many different forms. To cite one hypothetical case, if all 20 million cars in West Germany were to be powered with ethanol, one half of the country would have to be turned into sugarbeet fields. Otherwise, if West Germany and Brazil were to cooperate, all German and Brazilian cars could be powered by ethanol, produced by converting some 2 per cent of Brazilian land from forest into sugar cane fields (Hans-Jurger Rehm in Gierch (Ed), 1981). But what would be the consequences to Brazil in terms of its environment and social structures which would be caused by the uprooting of forest dwellers?

(a) Priorities

Priorities will differ according to the situation of individual developing countries. They can be determined in different ways. It is suggested that criteria for determining priorities might include: import substitution; developing alternative uses for raw materials whose export demand might diminish (e.g. cattle feed concentrates); manufacturing biotechnological products aimed at solving chronic national problems (e.g. pharmaceuticals for endemic diseases); and exploiting a country's natural advantage in certain feedstock for high-tech biotechnology products.

Table 6 (page 393) lists some biotechnology products categorised according to volume and value. Perhaps a developing country could start with 'high volume, low value' products and move to 'low volume, high value' lines as its infrastructures and human resources develop.

Table 6

BIOTECHNOLOGY: BASED ON VOLUME AND VALUE

Category	Products
High volume, low value	methane, ethanol biomass animal feed water purification,effluent and waste treatment
High volume, intermediate value	amino and organic acids food products baker's yeast acetone, butanol polymers metals
Low volume, high value	antibiotics and other health care products enzymes vitamins

From: Bull *et al*, Biotechnology: International Trends and Perspectives, OECD, Paris, 1982

What is important is that the developing countries take early steps to decide their national priorities and objectives in regard to biotechnology. A multidisciplinary team of experts could be set up to advise the government, as the Spinks' team (Anonymous, 1980) has done for Britain.

The areas of biotechnology (both traditional and high-tech) which will probably be of most immediate interest to Third World countries are given in Table 7 (page 394) Some of these will be of particular interest to those countries in a position to invest. Historically this has been shown with respect to oil exporting countries, eight of which (viz. Algeria, Indonesia, Iran, Iraq, Mexico, Nigeria, Saudi Arabia and Venezuela) achieved a per capita income growth rate of 5.6 per cent from 1970 to 1977. During this period, higher incomes caused an extraordinary rise in food demand in these countries, and as a consequence, their food imports grew at an unprecedented rate of

Table 7

AREAS OF BIOTECHNOLOGY OF IMMEDIATE INTEREST TO DEVELOPING COUNTRIES

Anaerobic digestion	Biological pest control
Biological nitrogen and phosphorus removal from waste water	Vaccine production (human and animal)
Plant breeding to evolve crops and crop varieties for meeting specific needs, e.g.drought resistance/tolerance, and to improve staple foods	Enzyme production (e.g. of isomerases, proteinases and urease)
Livestock improvement	
Aquaculture development	
Biological nitrogen fixation	Fermentation (alcohol, antibiotics,gluconic acid, phenylglycine)
Dairy and other food biotechnology	
Vegetable clonal propagation of crop plants using tissue culture techniques	
Application of *in vitro* techniques to breeding and selection of crop plants relevant to local situations	

19 per cent per year (Swaminathan, 1983). Some of these countries should be able to achieve higher domestic production of food by taking advantage of advances in biotechnology. Even high-tech biotechnology should interest them as a means of sustaining incomes when their oil resources are depleted.

(b) Infrastructure and management

It has earlier been pointed out that many Third World countries have not derived the full benefits of traditional biotechnology. The main causes, apart from issues such as price policy for agricultural production, have been lack of infrastructures and management support. To help remedy these deficiencies, it is suggested that those countries which have not already done so, should set up high-powered national biotechnology boards or commissions to advise governments, oversee developments, coordinate measures, and sponsor R&D, etc. For small island and other countries in areas which have effective regional organisations, such bodies could be set up regionally, e.g. in CARICOM, SPEC, and SADCC.

The universities and other relevant academic and research institutions should become more involved in biotechnology and be encouraged and supported in taking up R&D projects according to national priorities. There should be better links between academic institutions and industry in the development of biotechnology.

More effective long-term planning will be needed for human resource development. New courses will often have to be designed and more training inside and outside the country will be essential. Commonwealth institutions can help to organise such training programmes.

(c) <u>Communication and information exchanges</u>

Conflicts can arise between the desire to publish scientific findings and the need to protect inventions. A system which allows the free flow and interchange of scientific knowledge and, at the same time, encourages investment by providing protection to commercial companies (under some regulatory control against unethical and exploitative practices) is the ideal towards which practice should aim.

At the international level a body similar to the Consultative Group for International Agricultural Research (CGIAR) seems necessary for biotechnology. Sponsored in 1971 by the World Bank, FAO and UNDP, the CGIAR has subsequently been involved in the establishment of several first-rate international institutions for agricultural research, including the

International Board for Plant Genetic Resources (IBPGR). International agricultural research institutes established earlier have also been linked to the CGIAR. This linked system offers a formidable network for the diffusion and potential development of new technologies and applications. The Microbial Resource Centres (MIRCENs) established by a joint programme of UNEP/UNESCO/ICRO should help to fill the gap. Such a network, with established local centres in the Third World, should prove effective and useful. An interesting contemporary development is the 'Technical Centre for Agricultural and Rural Cooperation', envisaged by the EEC for the third Lome Convention which, it has been suggested, would link EEC R&D programmes in science and technology with the national programmes of the ACP countries (FAST Report, 1984). The establishment of the International Centre for Genetic Engineering and Biotechnology (ICGEB) in India and Italy will also be of value to Third World countries.

But despite the above international developments, more positive action is necessary to establish a network for communication and information exchanges in biotechnology and to sponsor and support R&D in the developing countries. The Commonwealth has the potential to play a significant role in this regard by virtue of its composition.

Some Conclusions

Biotechnology is multidisciplinary in nature and its full potential is yet to unfold. It has no universally accepted definition, but in view of its relevance to the Third World, this Paper has suggested that a wide ranging conception should be used, including both traditional and new or high-tech biotechnology.

The potential benefits from achievements in traditional biotechnology, like plant breeding, *Rhizobium* cultures, biogas, aquaculture, etc., have yet to be realised in many developing countries. The new biotechnology has even greater potential for benefits in these countries, offering possible solutions to some of their major problems. In fact biotechnology should now be considered fundamental to the future optimal global use of renewable resources. The Third World is richly endowed with many of the resources which supply feedstocks to biotechnology products. Recent advances have opened up vast fields for its application in food and agriculture, waste recycling and pollution control, alternative energy sources, chemicals and pharmaceuticals, medical and veterinary care, etc.

Clearly there are areas of vast potential for biotechnology in the Third World. And in an age of great scientific and technological advancement, developing countries cannot afford to be second or third in some of these crucial areas. These countries must decide their own priorities in developing and using biotechnology according to their own particular situations. In deciding priorities, the determining factors could be, e.g., import substitution, optimal use of raw materials for biotechnological products, alternative uses of raw materials which might ultimately not have much export demand, manufacture of biotechnological products to solve problems such as endemic diseases and pests, malnutrition, pollution, etc.

Biotechnology also offers vast potential for North-South collaboration. The developing countries should, however, be vigilant against the industrial countries exploiting their feedstock resources or using them as testing grounds for products of uncertain public safety. They should also guard against any unethical commercial practices by transnational companies.

Governments should support R&D in biotechnology and encourage the involvement of universities and academic and research institutions, as well as provide appropriate inducements to private enterprise. There will be need to develop the human resource base and establish sound infrastructures.

Support for the Third World in developing biotechnology is also needed at the international level, particularly in regard to assistance in establishing a network for communication and information exchanges and making available technical and financial assistance.

There is much to be done.

Acknowledgements

In preparing this paper, the author has drawn on a large number of studies and research papers and has been aided by a number of persons with whom he has had most fruitful discussions. He is very grateful to all of them. In particular, he would like to thank Prof.D.L. Hawksworth, Director, and Dr.D. Allsopp, Commercial Microbiologist, Commonwealth Mycological Institute; Dr.B. Persaud, Director and Head, Economic Affairs Division, Mr.I.R. Thomas and Miss S. Hyne of the same Division, and Prof.J.I.D.R. Furtado, Science Adviser, Commonwealth Secretariat. His special thanks are due to Sir Peter Marshall, Commonwealth Deputy Secretary-General, for encouraging him to write the paper.

APPENDIX I

SOME RECENT DEFINITIONS OF BIOTECHNOLOGY

1. 'Biotechnology is concerned with the use of biological activities in the context of technical processes and industrial production. It involves the application of microbiology and biochemistry in conjunction with technical chemistry and process engineering.'

   Biotechnologie, Eine Studie uber Forschung und Entwicklung, Dechema (1976).

2. 'The application of biological organisms, systems, or processes to manufacturing and service industries.'

   Biotechnology - Report of a Joint Working Party, UK (1980).

3. 'The application of biological organisms, systems or processes to manufacturing or service industries.'

   Biotechnology in Canada: Promises and Concerns (1980).

4. 'The utilization of a biological process, be it microbial, plant or animal cells, or their constituents, to provide goods and services.'

   Biotechnology: A Development Plan for Canada (1981).

5. 'The science of production processes based on the action of micro-organisms and their active components, and of production processes involving the use of cells and tissues from higher organisms. Medical technology, agriculture and traditional crop breeding are not generally regarded as biotechnology.'

   Biotechnology: a Dutch Perspective (1981).

6. 'The devising, optimising and scaling-up of biochemical and cellular processes for the industrial production of useful compounds and related applications. This definition envisages biotechnology as embracing all aspects of processes of which the central and most characteristic feature is the involvement of biological catalysts. Plant agronomy falls outside this definition but plants provide the raw material for most biotechnological processes, so research in plant breeding and productivity is of direct importance.'

   Biotechnology for Australia (1981).

7. 'The collection of industrial processes that involve the use of biological systems (in glossary). The use of living organisms or their components in industrial processes.'

   OTA Report - Impacts of Applied Genetics (1981).

8. 'The industrial processing of materials by micro-organisms and other biological agents to provide desirable goods and services.'

   FAST (Forecasting and Assessment for Science and Technology).

   Sub-programme Bio-society - research activities.

9. 'The integrated use of biochemistry, microbiology and engineering sciences in order to achieve technological (industrial) application of the capabilities of micro-organisms, cultured tissue cells, and parts thereof.'

   European Federation of Biotechnology (1981).

10. 'The application of biochemistry, biology, microbiology and chemical engineering to industrial processes and products (including here the products in health care, energy and agriculture) and on the environment.'

    International Unions of Pure and Applied Chemistry (1981).

11. 'The application of scientific and engineering principles to the processing of materials by biological agents to provide goods and services.'

    OECD Report (1982).

12. 'Biotechnology deals with the introduction of biological methods within the framework of technical processes and industrial production. It involves the application of microbiology and biochemistry together with technical chemistry and process engineering.'

    Federal Republic of Germany.

13. 'Biotechnology consists of the industrial exploitation of the potential of micro-organisms, animal and plant cells, and subcellular fractions derived from them.'

    France

14. 'A technology using biological phenomena for copying and manufacturing various kinds of useful substances.'

    Japan

15. 'The Swiss Government uses the same definition the European Federation of Biotechnology uses.'

    Switzerland

Sources

No.1 to 11: Bull et al, Biotechnology: International Trends and Perspectives; OECD, Paris, 1982.

No.12 to 15: Office of Technology Assessment, Commercial Biotechnology: An International Analysis; US Congress, Washington D.C., January 1984.

APPENDIX II

BIOTECHNOLOGY: ACCORDING TO INDUSTRIAL SECTORS

Sector	Activities
Chemicals: organic (bulk)	ethanol, acetone, butanol organic acids (citric, itaconic)
organic (fine)	enzymes perfumeries polymers (mainly polysaccharides)
inorganic	metal beneficiation, bioaccumulation and leaching (Cu, U)
Pharmaceuticals	antibiotics diagnostic agents (enzymes, antibodies) enzyme inhibitors steroids vaccines
Energy	ethanol (gasohol) methane (biogas) biomass
Food	dairy, fish and meat products beverages (alcoholic, tea and coffee) baker's yeast food additives (antioxidants, colours, flavours, stabilizers) novel foods mushroom production amino acids, vitamins starch products glucose and high fructose syrups functional modifications of protein, pectins toxin removal
Agriculture	animal feedstuffs veterinary vaccines ensilage and composting processes microbial pesticides Rhizobium and other N-fixing bacterial inoculants mycorrhizal inoculants plant cell and tissue culture (vegetative propagation, embryo production, genetic improvement)
Service Industries	water purification effluent treatment waste management oil recovery analytical tools

Source: Bull et al, Biotechnology: International Trends and Perspectives; OECD, Paris, 1982.

APPENDIX III

SOME EXAMPLES OF APPLICATIONS OF GENETIC MANIPULATION IN BIOTECHNOLOGY

HUMAN HEALTH

1. Monoclonal antibodies (for purification techniques, assays, tissue typing, in vivo tumour location, clinical diagnosis, therapy, including targeting of chemotherapeutic agents).
2. Interferon (possible use for cancer treatment, antiviral therapy, inflammatory diseases).
3. Vaccines (against, e.g., hepatitis B, influenza, malaria, encephalitis, cholera, herpes, adenovirus).
4. Hormones (e.g. growth hormones, insulin, prolactin, relaxin, gastrin, erythropoietin, thrombopoietin, chorionic gonadotropin, menopausal gonadotropin, steroids).
5. Enzymes (e.g. urokinase, heparinase, alcohol dehydrogenase).
6. Other proteins (e.g. specific antigens, blood factor, albumin, antithrombin, fibronectin).
7. Improved and new antibiotics, drugs, vitamins.
8. Gene therapy for genetic diseases.

B. : FOOD, AGRICULTURE AND HORTICULTURE

1. Enzymes (e.g. amylases, rennin, B-galactosidase, invertase, glucose isomerase, pectinases).
2. Food additives (e.g. sweeteners, aromas, flavours, colouring matter, thickeners and stabilizers, vitamins, amino acids, antioxidants, preservatives, surfactants).
3. Additions for animal feed (e.g. new antibiotics).
4. Improved and new plant varieties (including enhanced yields, crops specifically designed for particular land use, genes for proteins such as casein introduced into carbohydrate predominant crops) .
5. Pesticides and herbicides with increased specificity (e.g. use of bacillus thuringensis products, verticillium, taculoviruses, parasitic nematocides, protozoan, piperidine derivatives).
6. Vaccines (against, e.g., diarrhoeal colibacillosis, foot and mouth disease).

...Cont.

7. Plant growth hormones (e.g. cytokinins).

8. Fertilizers, microbial nitrogen fixation and manipulation of symbionts.

9. Diagnostic reagents for plant and animal diseases.

<u>ENERGY, RAW MATERIALS, CHEMICALS AND ENVIRONMENTAL MANAGEMENT</u>

1. Biomass from chemicals, wastes, residues and fuel crops (including production of ethanol, methanol, methane and SCP).

2. Enhanced oil recovery (e.g. xanthan gum, surfactants).

3. Improved algal cultures for use in photobioreactors (production of, e.g.,carbohydrate, protein, lipids, hydrocarbons).

4. Hydrogen and carbon dioxide production.

5. Chemicals and solvents (acetic acid, adipic acid, butanol, isopropanol, acetone, furfural, glycerol, waxes, polymers, alkene oxides and glycols, lubricants).

6. Metal extraction (e.g. copper, uranium, nickel, zinc, lead) from low grade minerals and recovery of valuable metals (e.g. mercury, cobalt).

7. Decomposition and detoxification of chemicals (e.g. oil spills, dalapon, pentachlorophenol).

8. Improved microbial systems for environmental control of air, water and soil.

Source: Bull et al, Biotechnology: International Trends and Perspectives, OECD, Paris, 1982.

APPENDIX IV

SOME BIOTECHNOLOGY MARKET FORECASTS

Commercial area	Estimated Market	Time Scale
1 PHARMACEUTICALS		
(a) Diagnostics	$2,000m including non-radioactive kits and monoclonal RAA kits	Already on the market. Could reach full potential by 1990. Best short-term return.
(b) Drugs	$8,000m by early 1990s, increasing thereafter according to new developments	Only one product (Humulin) on the market to date. Up-front costs and regulatory delays make this a vast but long-term field.
(c) Veterinary	$2,000m by 1990	Good short-term potential due to less stringent regulations. Market growth depends on farming economics.
2 AGRICULTURE	Impossible to quantify	Attractive medium-term area with worldwide potential once scientific problems overcome.
3 WASTE PROCESSING/ POLLUTION CONTROL	Biotech applications could reach $2,000m by 1990. Increased environmental concern would help	Already in use in some areas. Medium/long-term view.
4 BIOTECHNOLOGY EQUIPMENT & SUPPLIES	Currently estimated at about $200m per year: growth very rapid	A good short-term 'backdoor' method of gaining profits from biotechnology.
5 FOOD & DRINK	Impossible to quantify	Human food likely to encounter consumer resistance. Fair medium-term potential for animal feedstuffs.
6 MINERALS/OILS	Has been estimated at $4,500m by end of century	Interesting but speculative area, dependent on economics of mineral and oil extraction.

....Cont.

Commercial area	Estimated Market	Time Scale
7 INDUSTRIAL CHEMICALS		
(a) Enzymes	Uncertain. Dependent on economics of alternative non-biotech methods of enzyme	Long-term view necessary
(b) Amino acids	$3,600m by 1990	Most promising area for biotechnology in the chemical industry
(c) Plastics	Uncertain.	Unlikely to become economically viable before end of the century.
(d) Bulk chemicals/ synfuels	Uncertain.	Outlook depends on long-term oil price prospects. Could become attractive by end of century.

Source: Elkington, J., Biotechnology and Employment: the Integration of Traditional Economic Activities; Case study prepared for ILO, October 1983.

(Based on Laing and Cruickshank, slightly modified.)

APPENDIX V

MARKET PREDICTIONS FOR IMPLEMENTATION IN PRODUCTION OF GENETIC ENGINEERING PROCEDURES

Product category	Number of compounds	Current market value (million $)	Selected compound or use	Time needed to implement genetic production (years)
Amino acids	9	1,703	Glutamate Tryptophan	5 5
Vitamins	6	667.7	Vitamin C Vitamin E	10 15
Enzymes	11	217.7	Pepsin	5
Steroid hormones	6	367.8	Cortisone	10
Peptide hormones	9	268.7	Human growth Hormone Insulin	5 5
Viral antigens	9	n.a.	Foot-and-mouth disease virus Influenza viruses	5 10
Short peptides	2	4.4	Aspartame	5
Miscellaneous proteins	2	300	Interferon	5
Antibiotics	4*	4,240	Penicillins Erythromycins	10 10
Pesticides	2*	100	Microbial Aromatics	5 10
Methane	1	12,572	Methane	10
Aliphatics (other than methane)	24	2,737.5	Ethanol Ethylene glycol Propylene glycol Isobutylene	5 5 10 10
Aromatics	10	1,250.9	Aspirin Phenol	5 10

...Cont.

Product Category	Number of compounds	Current market value (million $)	Selected compound or use	Time needed to implement genetic production (years)
Inorganics	2	2,681	Hydrogen Ammonia	15 15
Mineral leaching	5	n.a.	Uranium Cobalt Iron	
Biodegradation	n.a.	n.a.	Removal of organic phosphates	

n.a. Not available.
* Number indicates classes of compounds rather than number of compounds.

Source: Bull et al, Biotechnology: International Trends and Perspectives; OECD, Paris, 1982.

(Quoting U.S. Congress Office of Technology Assessment; Genex Corporation; Industry Week, 7 September 1981, p.68.)

APPENDIX VI

VALUE OF APPLIED GENETICS AND NEW BIOTECHNOLOGIES IN VARIOUS SECTORS OF UNITED STATES MARKET

Market Sector	1981 $m	1985 $m	1990 $m	Average annual increase (%)
Diagnostics	6.0	45.0	2,525.0	95.6
Vaccines/Antigens	0.0.	25.0	1,000.0	259
Pharmaceuticals	20.0	380.0	7,180.0	92
Chemicals	1.0	10.0	270.0	86
Plant agriculture	0.1	0.5	2.5	43
Animal agriculture	8.0	59.0	433.0	5.8
Processed foods (incl.alcoholic drinks, sweeteners, bread, dairy, etc.	22.5	199.5	1,847.5	63
Misc.applications (mining, waste treatment, etc.)	1.5	13.5	120.00	63
Total	59.11	732.5	13,378	82.6

Source: Elkington, J., Biotechnology and Employment: the Integration of Traditional Economic Activities; Case study prepared for the ILO, October 1983.

(Quoting Business Communications Co.)

REFERENCES

(1) Anonymous (1979) Microbial Processes: Promising Technologies for Developing Countries. Report of an Ad Hoc Panel of the Advisory Committee of Technology Innovation; Board on Science and Technology for International Development, Commission on International Relations, National Research Council, National Academy of Sciences, Washington, D.C.

(2) Anonymous (1980) Biotechnology: Report of a Joint Working Party. Advisory Council for Applied Research and Development, Advisory Board for the Research Councils. The Royal Society, H M S O, London.

(3) Anonymous (1980 a) North-South: A Program for Survival. The Report of the Independent Commission on International Development Issues (Brandt Commission Report), Pan Books Ltd., London.

(4) Anonymous (1981) "Genetic Engineering for Crop Improvement." A Rockefeller Foundation Conference, May 12-15, 1980, New York (Working Paper).

(5) Anonymous (1982) Priorities in Biotechnology Research for International Development. Proceedings of a Workshop. Board on Science and Technology for International Development, Office of International Affairs, National Research Council. National Academy Press, Washington D.C.

(6) Anonymous (1984) "Commercial Biotechnology: An International Analysis." Published by the Office of Technology Assessment, US Congress, Washington, D.C.

(7) Borlaug, Norman E. (1983) "Contributions of Conventional Plant Breeding to Food Production." Science, Vol. 219, No. 4585, pp. 689-693.

(8) Bull, A.T., Holt, G. and Lilly, M.D. (1982). Biotechnology. International Trade and Perspectives. OECD, Paris

(9) Chaleff, R.S. (1983). "Isolation of agronomically useful mutants from plant cell culture." Science, Vol. 219, No. 4585, pp. 676-682.

(10) Edelman, J. (1984) Director of Research, Ranks Hovis McDougall (RHM), in a personal communication.

(11) Elkington, J. (1983) Biotechnology and Employment: the Integration of an Emerging Technology with Traditional Economic Activities. A case study prepared for the ILO, Geneva.

(12) Ekundayo, J.A. (1980) An Appraisal of advances in Biotechnology in Central Africa. In 'Fungal Biotechnology', The British Mycological Society - Symposium Series No. 3; Editors. Smith, J.E., Berry, D.R., and Kristiansen, B. Academic Press, London.

(13) Emejuaiwe, S.O., Ogunbi, O., and Sanni, S.O. (Editors) (1981) GIAM VI. Global Impacts of Applied Microbiology. Sixth International Conference 30 Aug.-7 Sept. 1980. Lagos Academy Press.

(14) Farnum, P., Timmis R., and Kulp, J.L. (1983) "Biotechnology of forest yield" Science Vol. 219 No. 4585. pp 694-702.

(15) FAST Report (1984). Eurofutures: The Challenges of Innovation. The Commission of the European Communities in Association with the Journal Futures. Butterworth and Co. (Publishers) Ltd., London.

(16) Fishlock, D. (1984) "Biotechnology." Financial Times, 11 Sept. 1984, pp.35-38.

(17) Giersch, H (Ed) (1982) Emerging Technologies: Consequences for Economic Growth, Structural Change and Employment. Tubingen, J Mohr.

(18) Greenshields, R.N. (1980). "Biotechnology in Malaysia". Fungal Biotechnology. The British Mycological Society Symposium No. 3. Editors: Smith, J.E., Berry, D.R., and Kristiansen, B. Academic Press.

(19) Hartley, B.S., (1984). "Impact of Biotechnology for Developing Countries of the Commonwealth." Paper written for the Commonwealth Science Council.

(20) Myers, N. (1984) "Genetic Resources". Paper written for the Commonwealth Science Council.

(21) Onions, A.H.S., Allsopp, D. and Eggins, H.O.W. (1981) Smith's Introduction to Industrialised Mycology. VII Edition, 1981. Edward Arnold, London.

(22) Simmonds, N.W. (1983) "Conference Review: Genetic Engineering of Plants." Trop. Agric. (Trinidad) Vol. 60, No. 1.

(23) Smith, J.E., Berry, D.R., and Kristiansen, B. (Editors) (1980). Fungal Biotechnology. The British Mycological Society, Symposium Series, No. 3, Academic Press, London.

(24) Swaminathan, M.S. (1983). "Agricultural Progress - Key to Third World Prosperity." Third World Lecture, 1983, Third World Foundation,Monograph II, Third World Foundation, London.

(25) Swaminathan, M.S. (1983a). "Genetic Conservation: Microbes to Man." Presidential Address, XV International Congress of Genetics, New Delhi, India.

(26) Vasudeva, R.S. and Azad, R.N. (1952). "Investigations on potato disease and production of disease free seed potatoes in India." Emp. J. Exp. Agric., Vol. 20,No. 8, pp.293-300, 1952; and Annual Reports of Div. of Myco., Indian Agric. Res. Inst., New Delhi, 1952-55.

(27) Watanabe,S. (1984) "Biotechnology: Employment Implications for Africa." Technology and Employment Branch, ILO, Geneva.

Printed and published by
The Commonwealth Secretariat

May be purchased from
Commonwealth Secretariat Publications
Marlborough House
London SW1Y 5HX

ISBN 0 85092 289 5

ISBN 978-1-84859-407-4