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UNITED NATIONS INDUSTRIAL DEVELOPMENT ORGANIZATION
Vienna International Centre, P.O. Box 300, 1400 Vienna, Austria
Tel: (+43-1) 26026-0 · www.unido.org · unido@unido.org

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TECHNOLOGY TRENDS SERIES NO. 7

The Changing Technological Scene: The Case of OECD Countries*

by

Sally Wyatt**
UNIDO Consultant

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** Economic and Social Research Council, United Kingdom. Ms. Wyatt produced the draft, which was revised with further inputs by the UNIDO Secretariat.

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Explanatory notes

Reference to "dollars" ($) are to United States dollars.

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Summary

The report deals essentially with the major currents of technological change as they are seen in relation to the OECD countries. It attempts to present and juxtapose the impact of three technological advances (microelectronics and information technology, genetic engineering and biotechnology, and new materials) and to consider industrial and technological change in an interrelated fashion. It is addressed essentially to an audience of government policy-makers and decision-makers in government departments and enterprises in those countries, developed and developing, that wish to monitor technological change worldwide to facilitate their own decision-making.

The report covers, in relation to OECD countries, trends in research and development expenditure and patenting, important changes that are occurring in the industrial and technological structure, features of the overall technological flows between countries, and the modalities of those flows such as foreign investment and licensing. Also discussed are interrelated changes in the development of new materials and advances in manufacturing technology, both of which have important implications for international competitiveness. Relevant policy trends in OECD countries are also discussed. Implications for developing countries are briefly referred to.

It is concluded that the trends discussed such as the changing industrial and technological market structure, the new facets of university-industry collaboration, the new elements of transfer of technology and R&D relating to enterprises, and the emerging product continuum in information technology have obvious implications for enterprises, managers and government policy-makers. The management of technological change thus emerges as a major policy concern for all countries.

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Introduction

As part of its Programme on Technological Advances, UNIDO has been monitoring industrial and technological trends relating to the major technological advances characterising the present global scene. The monitoring ranges from publication of quarterly current awareness bulletins or "monitors" on microelectronics, genetic engineering and biotechnology and new materials to specific assessments of technological trends in selected technological fields, which are published as a series. In addition, UNIDO has been helping some developing countries in setting up mechanisms for monitoring technological trends. It is however realised that all developing countries will not be able to develop, in the short run, a capability for monitoring industrial and technological developments even though, as the Tbilisi Forum on Technological Advances and Development emphasized (UNIDO, 1983, ID/WG.389/6), governments of even countries at earlier stages of development ought to have as one of their basic functions the monitoring of technological trends and assessing the implications for themselves.

It is considered that in addition to promoting country-level actions, it will be useful for UNIDO to continue its role in monitoring and disseminating information on salient technological trends which could be a supplement to national monitoring efforts in countries where such efforts exist and which could provide a general base of information in those countries where such efforts have not yet commenced. It is to be appreciated in this context that countries at an early stage of development cannot be expected to have the financial resources and capabilities for monitoring and even if they did, do not have to duplicate their efforts. UNIDO has also been asked by a resolution of its Fourth General Conference (UNIDO, 1984, ID/CONF.5/Res. 2) not only to help countries in setting up national groups to monitor and assess national trends but also to continue monitoring world technology trends and the changing technology markets.

In light of the foregoing, the Development and Transfer of Technology Division of the Department for Industrial Promotion, Consultations and Technology has been giving thought to the preparation and publication of an annual global technology survey. It was realised that the field to be covered is vast and developments occur in a number of countries. It was therefore thought that while some salient trends could be covered at a general global level, each survey could in addition address itself to a detailed assessment of a specific sector or set of sectors. The lack of human and financial resources has prevented the undertaking of such a survey which is on all accounts an ambitious venture. It is however felt that UNIDO should work gradually towards this goal, beginning with technology trends in selected sectors and countries.

As an initial measure to test this idea, the present report has been prepared. It deals essentially with the major currents of technological change as they are seen in relation to the OECD countries. What it attempts is not new research but rather the analysis of diverse information and results of research in order to synthesise them into a coherent picture that will bring into relief not only the concurrent impact of several technologies but also the changes that are occurring in the industrial and technological market structure. Perhaps the distinguishing feature of this report is its attempt to present the impact of three important technological advances (namely, microelectronics and information technology, genetic engineering and biotechnology, and new materials) in one view and also to consider industrial and technological change in an interrelated fashion. Such an integrated view is essential so as to correspond to real life and a partial analysis may not be particularly useful, especially to policy-makers and decision-makers in certain sectors (for example, chemical and engineering industries) that get influenced by more than one of the technological advances.

References are made wherever possible to the implications of the trends analysed here for the industrial and the technological development of developing countries. However, within the scope of this report it has not been the aim to address the question of developing country responses. It is hoped, however, that policy-makers and decision-makers in developing countries will be able to study the trends presented in this report in relation to their own conditions and requirements. It is also hoped that in a future survey the actions taken by developing countries in response to technological change could be documented comprehensively by analysing the information collected by UNIDO in this area.

The information presented here covers several dimensions of technological change, namely, trends in ongoing research and comparative technological advantage; important changes that are occurring in the industrial and technological structure; features of the overall technology flows between countries; and modalities of such flows such as foreign investment and licensing. Also discussed are two interrelated changes viz. development of new materials and advances in manufacturing technology, both of which have important implications for international competitiveness.

A report of this type has necessarily to address a mixed audience of government policy-makers, decision-makers in government departments and enterprises, and technologists. Concepts have to be introduced and data have to be presented that may be known to one or other segments of the audience (though new concepts and data are also presented, particularly in chapter II). Having regard to these factors, the presentation of each of the diverse elements of the technological scene is generally brief and the reader wishing to explore in detail any particular aspect is invited to refer to the various references cited. The report is essentially an attempt at sensitisation, the point of departure being to juxtapose as many relevant elements of the technological scene as possible.

As a prelude to the subsequent chapters, it is useful to take note, briefly, of certain features of the convergence of technological advances.

Some regard current technological advances as the elements of a new long cycle of economic activity. It has been suggested that the first cycle was based on the diffusion of the steam engine and textile innovations during the end of the eighteenth century; the second on the railways and associated changes in mechanical engineering and iron and steel; and the third on electric power, the internal combustion engine and the chemical industry. It is now argued that microelectronics provides the basis for the fourth long cycle. In the long cycle approach the emphasis is on investment, particularly the ability of entrepreneurs to create new investment opportunities on the basis of scientific and technical inventions. Economic growth is viewed as a process of reallocating resources between industries, which necessarily leads to structural changes. This process, however, is not smooth and continuous since innovations are not distributed randomly throughout the system but tend to be concentrated in a few sectors; and, the diffusion process is also uneven. There may be a slow start, followed by fast growth and then by saturation and stagnation. Changing profit expectations influence the course of this growth. As new capacity is expanded, the potential for earning high profits may be eroded due to market saturation, a slowdown in technical change and changing input costs. However, this process towards maturation will take several decades, during which time the existing economic structure will be radically altered. (Freeman, 1982, pp. 3-5)

Whether or not the current technological advances constitute a long cycle, the fact of their convergence is recognised. Convergence implies not only the concurrent impact of different technological developments but also the synergy created by their interaction. The most significant interaction among technological advances is taking place in the field of microelectronics and telecommunications with supporting activities in the related materials. Cost reductions due to miniaturisation in electronics and the combination of computers and telecommunication systems have been the driving forces behind "information technology". In manufacturing, information technology has led to a high degree of flexibility in automation, new design and construction capabilities, and the computer-controlled handling of materials and machine tools. New devices for information handling have made an important impact on the office, while new services and products based on information technology have emerged in telecommunications and consumer durables. The developments in satellite communications, optical fibres, etc., have dramatically increased information flows and the access to information in a manner that the emerging configurations of an "information society" are, arguably, expected to bring about changes in the work place, in management, in public administration, in transborder data flows and in certain respects, in the autonomy and privacy of the individual.

At another level, the interaction between microelectronics and genetic engineering and biotechnology has given rise to bioinformatics. For example, gene synthesis can now be facilitated and accelerated through sequence libraries. Such libraries, which have started developing, provide predictions about the positions where specific enzymes are likely to cut the DNA chain and guide the construction of genes that will be effective in a particular micro-organism. Control of industrial fermentation processes can now be substantially improved through microelectronics. More generally, (a) information about bioresources can be stored, processed and used as a guide to research and development; and (b) computer simulation of biological activities is possible.

New materials accelerate applications, for example, in the sectors of electronics, biotechnology and biomimetics, optotechnology, new energies and aerospace. Taking fine ceramics as an example, in electronics they find use in IC base plates, in IC packages and in various others as electroceramics. Biotechnology, in turn, sees alumina, apatite hydroxide, etc., finding use in artificial bones and teeth by virtue of the biological adaptability and mechanical properties of these materials. The sector of optotechnology is led by optical fiber (silica) followed by laser oscillators and optical functional devices, e.g. single crystals of lithium tantalate. The new energy sector involves materials of the nuclear fusion reactor, those of gas turbines, and those of ceramic engines among others; fine ceramics plays the major role in this sector because of their characteristic heat insulation and resistance to heat. In the sector of aerospace technology, finally, almost all reinforcements used in composite materials are fine ceramics of one type or another, and the heat resistance tiles covering the external surface of the body of the space shuttle are nothing but a fine ceramic.

Convergence, however, is not a uniform process. It should be noted that the degree of maturation and the degree of diffusion of the technological advances varies. The difference in degree of maturation has been presented in terms of "times of the day for high technologies" as follows.

Figure A. Time of the day for high technologies

	2-	
	3-	Biotechnology (chemistry sector), space technology
	4-	Biotechnology (agricultural sector), engineering ceramics
	5-	Biotechnology (pharmaceutical sector)
	6-	Bioceramics, optical processing machines
	7-	Optical communication system, office automation, unmanned production facility system, i.e., factory automation
	8-	Carbon fibre, aeronautics
a.m.	9-	Engineering plastics
	10-	Electroceramics, industrial robots
	11-	Semiconductor, communication equipment
	12 o'clock-	Large computers
p.m.		

Source: H. Kimura, "Development Trends of New Materials", Jidosha Gijutsu (Tokyo, August 1985).

Useful insights into the nature of technological advances, their market scale and their implications for industry have also been provided by a detailed comparison that has been made by a researcher.

Table A. Comparison of the features of three major key technologies

Key technology	Electronics	Biotechnology	New raw material
Dawn of technology	Invention of the transistor of Shockley in 1948; invention of the IC in 1958	Discovery of a double spiral structure of DNA's in 1953	Development of ceramic package in 1950; discovery of an empla by DuPont in 1958
Basic principle	Physical science	Application technology based on biological science	Basic sciences i.e., physics and chemistry; application sciences, i.e, chemical, mechanical, and electronic engineering
Features of technology	Technology involving widespread application	One technology innovation rarely finds widespread application	Technologies relying on experience
Feature of the product	High degrees of freedom in the choice of raw material	An innovated technology, i.e., an advanced technology superseding the conventional technology, is applied in mass production	A new raw material technology is substantiated in products
Effect on cost down	Learning curve effect works		Learning curve (experience) effect works
Productivity	Large boosting effect	Contributing to the improvement of productivity or production technology of the entire industry	Decline during the period of transition from conventional materials
Conversion of technology costs to capital buildup	Possible, providing the relevant technology stay at or above the general technology level of the time		Not easy

continued

Table A. (continued)

Key technology	Electronics	Biotechnology	New raw material
User industry	Entire industry	Agriculture, chemical industry, pharmaceutical industry, food processing industry	Electronics, automobile, aerospace, etc.
Extended effect on industrial structure	Initiating and pushing the development of the society of high grade information network	Effect exerted on the entire industries and on social structure; innovation of production process	Serving to brace up the other high technology industries
Hard- and software orientation	Hardware oriented	Software oriented	Hardware (plus software) oriented
Time of maturation	Maturation in progress	Maturation in the year 2000	Maturation not before the year 1990
Scale of equipment investment	Y50 trillion in the coming decade	Y2 trillion in the coming decade	Y3 trillion in the coming decade
Possibility of development of related industry	Industry for producing apparatuses for use in semiconductor manufacture, software industries	Industry for manufacturing machines and equipments, engineering industries like that of vegetable factory	Industry for manufacturing machines and equipment
Factory siting	Industrial water, young and women labor force, access to airports and super highways, electric power, etc.	High quality water, access to airport and super highway access to universities (interdisciplinary buildup), etc.	Industrial water, electric power, interdisciplinary buildup, access to airport and super highway
Market scale	Y8.68 trillion in 1980; Y21 trillion in 1985	Y0 in 1983; Y100 billion or so in 1988; Y3-4 trillion in 2000	Y550 million in 1981; Y1.25 trillion in 1985
Growth	Over 20 percent per year		20-30 percent per year

continued

Table A. (continued)

Key technology	Electronics	Biotechnology	New raw material
Creation of employment	Small	Small	Small (capable of affording jobs to middle- and old-age workers and to physically handicapped workers)
International competition	The U.S. = Japan > Europe	The U.S. ≥ Japan ≥ Europe	The U.S. > Japan ≥ Europe
Hazard (Unfavorable effect on society)	Negative effect on employment		
Limitation in resources	Slight	Technology permits one to surmount the barrier of resource limitation	Raw material in abundance

Source: H. Kimura, "Development Trends of New Materials", Jidosha Gijutsu (Tokyo, August 1985), pp. 22-24.

I. INDICATORS OF SCIENTIFIC AND TECHNOLOGICAL TRENDS

This chapter examines recent trends in the development of scientific and technological knowledge as they give an indication of the types of technologies likely to emerge in the future. Information on technologies ranging from the simple to the sophisticated can help policy-makers and entrepreneurs decide where to invest their resources and to keep themselves current about what the competitors - other countries or other firms - are up to.

Unfortunately, no single indicator gives an accurate picture of the state of scientific and technological knowledge. For example, R&D expenditure data do not capture the innovative activities of firms that do not have formal R&D departments. Thus, the innovative activities of mechanical engineering firms often appear extremely limited. Patent data also tend to underestimate the innovative activities of firms involved in defense-related R&D. Since patent specifications are in the public domain, firms often choose or are obliged by governments to keep technical details as confidential as possible when questions of national security arise.

Researchers and policy-makers have attempted to develop a range of science and technology (S&T) indicators. Each indicator can be found along a continuum beginning with the generation of basic knowledge, leading to industrial and other applications, and ending with their socio-economic impact. Of course real life complicates this neat categorisation, but the indicators can usually be classified under one of three groups:

"Input" indicators	"Output" indicators (1)	"Impact" indicators
R&D expenditure	patents	productivity indices
employment of scientists and engineers	technological balance of payments	trade in technology-intensive products
	scientific publications	patterns of compet-titive advantage

This chapter focuses on R&D expenditure and patenting activity, comparing differences among countries and sectors.

A. International comparisons

1. R&D expenditure and personnel

Figure I shows the ratio of R&D expenditure to gross national product (GNP) for the Federal Republic of Germany (FRG), France, Japan, the Union of Soviet Socialist Republics (USSR) and the United States. If defence spending is excluded, the U.S. figure for 1983 drops from 2.6 per cent to 1.8 per cent, well below the share of the FRG of 2.6 per cent and Japan's 2.5 per cent. (Technical Insights Inc., 1986, p. 308)

In countries of the Organisation for Economic Co-operation and Development (OECD), the following trends in R&D spending have been observed: (OECD, "Productivity in Industry, Prospects and Policies", 1986, pp. 16-17).

(a) Overall growth in R&D spending has slowed down after rising by 5.5 per cent a year between 1979 and 1981. Between 1981 and 1983, the rise was 4 per cent.

(b) R&D is heavily concentrated in the largest countries. In 1983, the seven largest OECD member countries (2) accounted for 92 per cent of total R&D expenditure in the OECD area.

(c) Between 1979 and 1983, R&D grew twice as rapidly in Japan as in either the United States or the European Community (EC). The United States remains the single largest spender on R&D. The combined expenditures of the EC countries is still much larger than Japan's, although the gap is closing rapidly.

(d) R&D either kept abreast of, or grew more rapidly than economic growth in most countries. Figure II shows that the percentage of GNP devoted to R&D has been rising. Tables 1 and 2 show government R&D funding and total R&D spending as percentages of gross domestic product (GDP) in OECD countries in recent years.

(e) Since the late 1970s, within most member countries and the OECD as a whole, the private sector has replaced the public sector as the major source of R&D finance. This is despite the large increase in (government-financed) defence spending in the United States.

(f) Since 1979 R&D has grown more rapidly than capital investment except in Japan and in some of the smaller OECD member countries. This pattern has been reinforced by the slow growth rates in capital investment in recent years.

(g) Most government funding is devoted to defence and space programmes, particularly in France, Sweden, the United Kingdom and the United States. Government support for R&D in energy is declining after a period of rapid growth. Figure II gives the per capita figures of public support for R&D in 1983, according to four socio-economic objectives. (Energy is included in the "economic development" category.)

(h) Table 3 shows the sources of funds for R&D by broad industrial classes in the United States, 50 per cent of the funds going to the aerospace industry and to the electrical machinery and communications industry - two sectors where governments funds are also channelled highest.

Aggregate figures for Western Europe disguise wide differences among individual countries. Between 1967 and 1982, Belgium, Ireland and Sweden increased their R&D spending at a creditable rate of more than 6 per cent per annum. During the same period, France, the FRG and Italy also exhibited a reasonable 5 to 6 per cent annual rate of increase. The Netherlands, Switzerland and the United Kingdom, however, managed annual R&D increases of only 1.5 per cent, 1.2 per cent and 0.9 per cent, respectively. (Patel and Pavitt, 1986, pp. 21-25)

In addition to increase in R&D expenditure, there is a qualitative change occurring in view of the recognition in the mid-70s that R&D is not the same thing as innovation. This has resulted in certain policy reorientations, which are discussed in chapter VI.

2. Other S&T indicators

The OECD has observed the following trends in patenting activity: (OECD, "Productivity in Industry, Prospects and Policies", 1986, p. 19)

(a) Patenting activity generally stagnated or declined in the OECD area through the end of the 1970s, picking up again in recent years.

(b) Domestic patenting is growing more slowly than R&D expenditure. Whether this reflects a decline in the propensity to patent R&D results or merely implies an increase in the costs associated with new inventions is not clear.

(c) Japan patents more than any other OECD country and has not followed the apparent general decline in patent productivity.

Table 4 summarises the relative standing of Japan, Western Europe and the United States in a number of sectors, based on industry-financed R&D, patents granted in the United States, the commercialisation and diffusion of specific innovations, and peer judgements.

Western Europe appears to be in a strong position in chemicals and nuclear energy, is ahead of the United States in metals and automobiles, and is ahead of Japan in aerospace and technologies for exploiting raw materials. Western Europe is also in a solid position in conventional industrial machines and production engineering, although this is being challenged by Japan's electronics-based technology. The region's technological hold in electronics - with the exception of software - is weak compared with the United States and Japan.

The technological strengths of the United States lie in aerospace- and raw materials-based technologies, its weaknesses in metals and automobiles. The United States is behind Western Europe in chemicals and is now being threatened in electronics by Japan. Japan is clearly ahead in electronics, automobiles and metals, but is behind in aerospace-, chemical- and raw material-based technologies. (Patel and Pavitt, 1986, pp. 69-71)

Tables 5, 6 and 7 present a detailed industrial breakdown of American, West European and Japanese technological strengths and weaknesses, and how these have changed over time. The information has been compiled on the basis of an index derived from U.S. patenting data (3).

Table 5 shows that the relative strengths of the United States are in technologies linked to natural resources: food and tobacco, petroleum and natural gas, farm and garden machinery, construction and mining machinery, and refrigeration machinery. Other leading sectors are technologies receiving considerable government support: guided missiles and space vehicles, and aircraft and parts. The United States is quite competitive in some electronics products - office equipment, electronic components and telecommunications - but its edge in these areas is declining.

Table 6 shows that Western Europe's technological advantages lie in chemicals, machinery, motor vehicles, nuclear energy and aircraft. Its weak and declining industries include those in the information technology areas.

Table 7 shows that Japan's most dynamic sectors are electronics, motor vehicles, metals, engines and turbines. Japan is relatively weak in the natural resources-based technologies, nuclear energy, aircraft and guided missiles.

Of course simply knowing which countries are excelling at certain technologies is not enough. One must also be vigilant about which technologies are gaining in international competitive advantage. The following section examines S&T trends in a range of sectors.

B. Specific sectors

Despite the economic recession of recent years, R&D expenditure has grown considerably in the industrialised countries. In 1984, U.S. companies' investment in R&D jumped by almost a full percentage of sales to 2.9 per cent, having remained at 2 per cent for more than five years. (Business Week, 8 July 1985, p. 68) Business Week publishes an annual summary of U.S. industry's R&D spending, covering data for all publicly held companies with sales of at least $35 million and R&D expenditure of at least $1 million or 1 per cent of sales. The data account for more than 95 per cent of all private-sector R&D expenditure. However, there are two major gaps in the data: innovative activities of industrial firms that do not have formal R&D programmes, and R&D activities in the public sector. The latter are particularly important, especially activities in new technologies such as biotechnology and new materials, much of which is being done within academic institutions.

R&D joint ventures are a growing trend, most noticeably in chemicals and pharmaceuticals (particularly in biotechnology), new materials, electrical and electronic components and equipment, and communications. Agreements often involve American, European and Japanese firms. In biotechnology, firms are more likely to enter into ventures with academic and specialised research institutions. In electronics and communications, agreements tend to be between leading firms in different but related areas, enabling the partners to keep pace with the convergence of their own specialities and to take advantage of the increasingly expensive integrated products and systems. (Vickery, 1986, p. 38)

Another growing phenomenon are science parks. Often promoted by governments, science parks are seen as benefiting all parties - providing industry with easy access to recent scientific advances (now crucial as the scientific base of the new technologies industry is growing) and providing the academic community with access to financial resources and to real-world applications for their ideas. A recent survey of five European countries revealed that they had only 10 science parks in 1980; by 1985 they had 47.

1. Information technology

Table 8 indicates where firms are investing their money - that is, mostly in information technology. (Much of automotive R&D could well be in new materials; ceramics are becoming more widely used in engines.)

Software is receiving a growing share of information technology R&D, as illustrated in Figure III. Much of the research directed at fifth-generation computers incorporates software, such as intelligent knowledge-based systems. Unfortunately software tends not to be patented because most patent systems regard it as similar to knowledge presented in books. (Only knowledge considered as being embodied in artefacts can be appropriated under the patent system.) Still, many companies continue to seek the protection offered by patents, making special efforts to incorporate their software into their hardware. Although R&D data show that software is a rapidly growing area, the same is not reflected in patent data.

Table 9 presents the Revealed Technological Advantage (RTA) indices (3) in electronics, telecommunications and instruments for France, the FRG, Japan, the United Kingdom and the United States. (The absolute volume of patenting in these areas has more than quadrupled over the last 20 years.) Japan's dynamism in all three areas emerges clearly, with each index well above 1. France is also strong in telecommunications. The FRG and the United Kingdom have lost whatever advantages they may have started out with. The U.S. indices show little variation, remaining relatively stable (4). (Soete, 1985, pp. 42-44)

Many countries are following Japan's lead and providing massive government support for fifth-generation systems featuring artificial intelligence, expert systems and VLSI (very large scale integration).

2. Biotechnology

A unique feature distinguishing the development of biotechnology products and processes from other technologies is the high degree of interaction between industrial and academic institutions. This can take several forms: consultancy, industrial associates programmes, research contracts, research partnerships and corporate funding for university researchers.

The extent to which this is happening has given rise to concern in several countries. Should universities grant exclusive licenses to companies that support research leading to a marketable product? Would not the university's primary function of teaching and research be distorted towards the dictates of the market? Will the knowledge generated within universities reach a wide audience? Will there remain a sufficiently large group of independent scientists who will be able to play a supervisory and advisory role to the government? In the industrialised countries - certainly in France, the United Kingdom and the United States - there is concern that although much of the basic research has been taking place within universities, financed significantly by public (in addition to private) money, it now appears that only a few will reap the private profits. This issue looms large in the United States where foreign companies finance research in American universities. (Dembo and Morehouse, 1987, pp. 6-17)

Several types of R&D co-operation have begun to emerge involving both small specialised biotechnology companies and transnational corporations, such as R&D arrangements, R&D limited partnerships, and marketing and testing arrangements. Table 10 contains some recent R&D ventures between small companies and transnational corporations, reflecting variety and flexibility to suit specific needs. In general, speciality biotechnology companies in the United States have attempted to finance R&D through several means such as venture capital; public stock offerings; transnational corporations (purchasing equity, joint ventures, contracts and/or licensing); R&D limited partnerships; and government support.

Table 11 reveals how much five governments spent on biotechnology R&D in 1982. The United States had a considerable lead. Expenditures of private companies in each of these countries was, however, not known.

Problems in the design, scale-up and optimal control of large-scale bioprocesses are still constraints in large-scale applications of biotechnology but these are being vigorously addressed in countries like Japan and the United States. In the meantime commercialisation has been most evident in pharmaceutical products and agricultural biotechnology. Several biotechnology health care products have already been brought to the market, as also have a number of diagnostic products based on monoclonal anti-bodies. It is reported that biotechnology companies and major pharmaceutical manufacturers have targeted nearly every major human disease and have already discovered proteins that appear useful in clinical trials in treating those diseases. (Baum, 1987) Agricultural biotechnology for farm animals and pets has benefited from the advances made by companies that have focused on the human health care side of biotechnology. Numerous agricultural biotechnology products ranging from animal vaccines to microbial pesticides to herbicide-resistant plants are now moving from the laboratory to the field for trials and eventual commercialisation.

3. Solar photovoltaics

The photovoltaic industry emerged in the post-1973 era. Since then, photovoltaic technology has gone through three stages associated with single-crystal, polycrystalline and amorphous conversion materials. These materials-based shifts have been financed largely by the public sector, with the pattern of support varying among countries. Support for R&D has been part of national programmes while access to markets have been facilitated through international agencies.

The trends at the international level relating to research and expenditure on solar energy are worth noting. (Juma, 1987, p. 7) In the United States, which has carried out substantial public spending of solar R&D, there is a trend towards reduction and setbacks in public sector R&D from $56[illegible] million in 1980 to $52 million forecast for 1987. The development of solar technology in the major producing countries has relied heavily on public sector support at three main levels: support for R&D, provision of markets and raising public awareness of the technology. Support for R&D has been conducted as national programmes, and expansion of the market has involved international agencies, which has led to the application of photovoltaic technology in the developing countries. While the R&D programmes set price goals in levels of efficiency to be achieved over specific time scales, the expansion of markets provided the financial as well as operating experience that were subsequently applied in R&D.

Most of the R&D in Japan, Western Europe and the United States has been done through complex government-industry, industry-university and government-university interlinkages. While the quantum of publicly funded R&D in the United States has been declining, different trends are visible in Europe and Japan. West European countries, under the auspices of the European Economic Community (EEC), launched a major programme in the late 1970s involving state agencies, universities, industry and public enterprises. Photovoltaics R&D accounted for $15.5 million over the 1975-79 period and was increased by some 190 per cent to reach $59 million over the 1979-83 period. The work in Europe was subcontracted to universities, research intitutes and industry in the various European countries. Like in the United States, the EEC programme underook R&D specifically to reduce selling costs through improved processing and alternative materials.

The European countries also support photovoltaic R&D through national programmes. France, for example, has set aside $154 million for photovoltaic development over the 1982-86 period of which the government's contribution amounts to $52 million. The FRG's Federal Ministry for Research and Technology spent the following amounts on photovoltaics research: During the 1972-77 period, DM 10 million (i.e. 4.5 per cent of total appropriations for research on non-nuclear energy); in the 1978-82 period this was increased to DM 95 million (9 per cent of total; from 1983-87, research expenditure on photovoltaics reached an all-time high of DM 300 million (28 per cent of total); and forecasts for the period 1988-92 expect a decline in non-nuclear research funding from DM 1.1 billion in 1988 to DM 810 million in 1992, with a corresponding reduction in photovoltaic research from DM 270 million in 1988 to DM 160 million in 1992 (26 per cent and 20 per cent of total, respectively).

Photovoltaic R&D in Japan is conducted under the Sunshine Project, launched in 1974. Funding for photovoltaics has been increasing rapidly. For example, funding was raised more than 140 per cent during the 1980-82 period alone, bringing the total allocation to $30 million. By 1984 Japan was spending some $16 million on photovoltaic R&D, shared equally between industry and government.

Even with the recent reductions in some national R&D budgets, an estimated $100 million per annum is spent worldwide on photovoltaic research.

A review of research institutes in developing countries carried out by UNIDO in 1982 and updated in 1985 and 1986 showed that out of 115 institutes included in the most recent review (UNIDO/IS.341/Rev. 2, 1986), 43 were involved with the research of photovoltaics (solar cell technology and systems) and 25 with solar thermal (flat plate and concentrating) collectors; 15 with solar thermal systems and 6 with selective coatings. Main applications were solar drying (47), water heating (33), cooling and refrigeration (24), solar cooker (16) and water pumping (13); 6 were engaged in research in industrial heat process.

The expenditure on R&D does now, however, appear to be considerable. An analysis of the research budgets for 1984-85 of institutes listed in the above review shows that these budgets range from $10,000 to several million dollars. At the low end of the scale are Iran, Trinidad and Tobago and Cameroon while Singapore and the Kingdom of Saudi Arabia are on top of the list with $12 million and $8 million, respectively. The great majority, however, have a rather modest budget of $100,000 to $200,000 with an average professional staff of five.

Notes

(1) Irvine and Martin (1985) have discussed the strategic uses of citation analysis and other bibliometric techniques. Interest in institutional arrangements as S&T indicators is growing.

(2) The seven largest OECD member countries are Canada, the Federal Republic of Germany, France, Italy, Japan, the United Kingdom and the United States.

(3) The Revealed Technological Advantage (RTA) index, developed by Soete in 1980, is a country's share of U.S. patenting within a sector, divided by that country's share of total U.S. patents. The index is equivalent to the Revealed Comparative Advantage index used by trade analysts. A value greater than 1 indicates a country's relative strength in a sector. Indices were calculated for the periods 1963-69 and 1977-83. In Tables 5, 6 and 7 a country is deemed to be increasing or decreasing its technological advantage in a particular sector if the RTA index increases or decreases by more than 5 per cent; a sector is deemed stable if the index changes by less than 5 per cent.

(4) The indices are less reliable for the United States since they are derived from U.S. patent data, which represent domestic patenting activity rather than foreign patenting activity. (For other countries the data reflect foreign patenting activity.) Foreign patents have been shown to be a more reliable indicator of quality.

Table 1. Government R&D funding as percentage of GDP

	1981	1982	1983	1984	1985
Austria	0.50	0.52	0.53	0.53	0.55
Belgium	0.62	0.63	0.58	0.57	—
Denmark	0.49	0.47	0.51	0.50	—
Finland	0.57	0.60	0.61	0.62	0.63
France	1.31	1.32	1.41	1.47	—
Germany	1.15	1.21	1.14	1.13	—
Greece	0.21	0.20	0.22	0.13	—
Ireland	0.40	0.39	0.41	0.39	—
Italy	0.65	0.64	0.71	0.72	—
Netherlands	0.98	1.06	1.01	0.97†	0.94†
Norway	0.75	0.79	0.77	—	—
Spain	0.27	0.28	0.26	—	—
Sweden	1.15	1.23	1.31	1.31	—
UK	1.41	1.33	1.33	1.35	1.34
US	1.15	1.19	1.18	1.22	1.30
Japan	0.64	0.63	0.63	—	—

Source: OECD/STIIU Data Bank - September 1985, cited in Financial Times, 30 June 1986.

* Estimates.

Table 2. Total R&D spending as percentage of GDP

	1981	1982	1983	1984	1985
Austria	1.17	1.22†	1.23†	1.25†	1.27†
Belgium	—	—	—	—	—
Denmark	1.07	1.13†	—	—	—
Finland	1.19	—	1.32	—	—
France	2.01	2.10	2.15	2.22†	2.27†
Germany	2.48	2.58†	2.58†	—	—
Greece	0.21	—	—	—	—
Ireland	0.75	0.75	—	—	—
Italy	1.01	1.04	1.20†	1.19†	—
Netherlands	1.88	1.98	2.03†	2.00†	—
Norway	1.29	—	1.41†	—	—
Spain	0.39	—	—	—	—
Sweden	2.22	—	2.47	—	—
UK	2.42	—	2.27†	—	—
US	2.51	2.66	2.70	2.70†	2.80†
Japan	2.37	2.47	2.61	—	—

† Estimates.

Source: OECD/STIIU Data Bank—September 1985.

Source: OECD/STIIU Data Bank - September 1985, cited in Financial Times, 30 June 1986.

Table 3. Estimated sources of funds for U.S. R&D by broad industrial classes, 1987

(millions of current US dollars)

	Federal Funds	Industry Funds	Total Funds	% Federal
Aerospace	$17,588	$ 5,968	$23,556	74.66
Electrical machinery and communications	7,396	13 958	21,354	34.63
Chemicals	315	10,508	10,823	2.91
Machinery	1,045	9,083	10,128	10.31
Autos, trucks & parts, & other transportation equipment	1,621	7,034	8,655	18.72
Professional & scientific instruments	751	5,382	6,133	12.24
Petroleum products	19	2,338	2,357	0.80
Rubber products	173	1,049	1,222	14.15
Food & beverage	0	1,043	1,043	0.00
Paper/Pulp	3	812	815	0.36
Fabricated metals & ordnance	43	745	788	5.45
Stone, clay & glass	92	629	721	12.76
Nonferrous metals	178	502	680	26.17
Iron & steel	185	458	643	28.77
Textiles	0	166	166	0.00
Other manufacturing	19	882	901	2.10
Total manufacturing	29,428	60,557	89,985	32.70
Nonmanufacturing	1,526	2,116	3,642	41.90
Total	$30,954	$62,673	$93,627	33.06

Source: Battelle, cited in Inside R&D, 31 December 1986, p. 7.

Table 4. Summary of relative technological levels of three regions

	JAPAN				USA				W.EUROPE			
	R&D	PAT [a/]	INN & DIFF [b/]	EXP [c/]	R&D	PAT	INN & DIFF	EXP	R&D	PAT	INN & DIFF	EXP
PHARACEUTICALS	)	2	2=	)	)	3	2=	) 1	)	1	1	)
	) 2			) 3	) 3			)	) 1			) 2
OTHER CHEMICALS	)	2	na	)	)	3	na	) 1	)	1	na	)
AEROSPACE	3	3	na	3	1	1	na	1	2	2	na	2
NUCLEAR ENERGY	na	3	na	3	na	2	na	2	na	1	na	1
METALS	1	1	1	2	3	3	3	3	2	2	2	1
AUTOMOBILES	1	1	na	na	3	3	na	na	2	2	na	na
RAW MATERIALS EXPLOITATION	na	3	na	3	na	1	na	1	na	2	na	2
MANUFACTURING												
Industrial Machinery	na	3	na	2	na	2	na	3	na	1	na	1
Production Engineering	na	na	na	2	na	na	na	3	na	na	na	1
Robots, NCMT, Instruments	na	1	1	1	na	2	2=	2=	na	3	2=	2=
ELECTRONICS												
Components	na	)	2	1	na	)	1	2	na	)	3	3
		) 1				) 2				) 3		
Tele-communications	na	)	na	2	na	)	na	1	na	)	na	3
Consumer	na	1	na	na	na	2	na	na	na	3	na	na
Office	na	1	na	na	na	2	na	na	na	3	na	na
Software	na	na	3	2	na	na	1	1	na	na	2	3

<u>Source</u>: P. Patel and K. Pavitt, <u>Measuring Europe's Technological Performance: Results and Prospects</u>, Science Policy Research Unit Working Document (Brighton, 1986), p. 70.

a/ Patents granted in the United States.
b/ Commercialisation and diffusion of specific innovations.
c/ Peer judgements.

Table 5. Patterns and trends of technological advantage in the U.S.A.

	INCREASING a/	STABLE	DECREASING a/
ADVANTAGE (RTA Index is greater than 1)	Petroleum & gas	Food	Rubber & plastics
	Fabricated metals	Soaps & detergents	
	Farm & gardening machinery	Paints & varnishes	
	Electrical lighting and wiring	Miscellaneous chemical products	
	Guided missiles and space vehicles	Construction & mining equipment	
	Aircraft & parts	Office computing	
		Refrigeration equipment	
		Electrical Transmission	
		Electronic Components and Telecommunications equipment	
		Household appliances	
DIS-ADVANTAGE (RTA Index is less than)	Industrial Inorganic chemistry	Industrial organic chemistry	Agricultural chemicals
	Nuclear reactors and systems	Plastics & synthetic resins	Ferrous & non ferrous products
		Drugs & medicines	Metal working machinery
		Stone, clay etc.	Special industrial machinery
		Engines & turbines	Miscellaneous non-electrical machinery
		General industrial machinery	Electrical industrial apparatus
		Miscellaneous electrical machinery	Radio & TV
		Instruments	Motor vehicles

Source: P. Patel and K. Pavitt, Measuring Europe's Technological Performance: Results and Prospects, Science Policy Research Unit Working Document (Brighton, 1986), p. 38.

a/ Refers to increase or decrease in RTA index of more than 5 per cent over the period 1963-1969 to 1976-1983.

Table 6. Patterns and trends of technological advantage in Western Europe

	INCREASING a/	STABLE	DECREASING a/
ADVANTAGE	Agricultural chemicals	Drugs & medicines	Industrial organic chemistry
	Soaps & detergents	Primary ferrous products	Industrial inorganic chemistry
	Metal working machinery	Special industrial machinery	Plastics and synthetic resins
	Household appliances	General industrial machinery	Primary and secondary nonferrous products
	Miscellaneous electrical machinery	Miscellaneous non-electrical machinery	Engines & turbines
	Nuclear reactors and systems	Electrical Industrial apparatus	Motor vehicles
	Aircraft & parts		
DIS-ADVANTAGE	Food	Paints & varnishes	Office computing
	Miscellaneous chemical products	Petroleum & gas	Radio & TV
	Fabricated metal	Rubber & plastics	Electronic components & Telecommunications equipment
	Farm & garden machinery	Electrical transmission	Instruments
	Construction & mining equipment	Guided missiles and space vehicles	
	Refrigeration equipment		
	Electric lighting & wiring		

Source: P. Patel and K. Pavitt, Measuring Europe's Technological Performance: Results and Prospects, Science Policy Research Unit Working Document (Brighton, 1986), p. 39.

a/ Refers to increase or decrease in RTA index of more than 5 per cent over the period 1963-1969 to 1976-1983.

Table 7. Patterns and trends of technological advantage in Japan

	INCREASING a/	STABLE	DECREASING a/
ADVANTAGE	Stone, clay etc	Electronic components & telecommunications equipment	Industrial Inorganic chemistry
	Engines & turbines		Industrial organic chemistry
	Office computing		Plastics & synthetic resins
	Miscellaneous non-electrical machinery		Agricultural chemicals
	Electrical industrial apparatus		Paints & varnishes
	Radio & TV		Miscellaneous chemical products
	Motor vehicles		Drugs & medicines
	Instruments		Rubber & miscellaneous plastic products
			Ferrous & non-ferrous products
			Miscellaneous electrical machinery
DIS-ADVANTAGE	Soaps & detergents	Paints & varnishes	Food
	Petroleum & gas		Farm & garden machinery
	Fabricated metals		Special indusustrial machinery
	Construction & mining equipment		Refrigeration machinery
	General industrial machinery		Household Appliances
	Electrical Transmission		Guided missiles and space vehicles
	Electrical lighting & wiring		Aircraft and parts
	Nuclear reactors and systems		

Source: P. Patel and K. Pavitt, *Measuring Europe's Technological Performance: Results and Prospects*, Science Policy Research Unit Working Document (Brighton, 1986), p. 40.

a/ Refers to increase or decrease in RTA index of more than 5 per cent over the period 1963-1969 to 1976-1983.

Table 8. Where U.S. R&D spending grew most in 1984

	% gain over 1983
Computer peripherals	41
Computer software	41
Semiconductors	32
Machine tools	22
Instruments	21
Computers	20
Electronics	19
Automotive	16
All-industry average	14

Source: Business Week, 8 July 1985, p. 68.

Table 9. Revealed technological advantage indices in electronics, telecommunications and instruments for the U.S.A., Japan, FRG, France and the U.K.

	1963-68	1969-74	1975-80	19[illegible]
USA				
Electronics	1.03	1.03	1.02	1.01
Telecommunications	1.01	1.04	1.07	1.04
Instruments	1.00	0.99	0.98	0.93
Japan				
Electronics	1.52	1.51	1.49	1.48
Telecommunications	1.20	1.07	1.26	1.12
Instruments	1.07	1.28	1.32	1.36
Germany (FR)				
Electronics	0.87	0.80	0.76	0.79
Telecommunications	0.75	0.74	0.64	0.58
Instruments	1.24	0.99	0.94	0.94
France				
Electronics	1.05	0.97	1.01	1.17
Telecommunications	1.32	1.64	1.64	1.97
Instruments	0.99	0.99	0.86	0.79
UK				
Electronics	1.13	1.03	0.91	0.83
Telecommunications	1.29	0.94	1.07	1.05
Instruments	0.90	0.90	0.87	0.80

Source: L. Soete, "Electronics", in Technological Trends and Employment: Electronics and Communications, L. Soete, ed. (Aldershot, U.K., Gower, 1985), p. 44.

Table 10. Some recent research and development arrangements

Research & development company or university	Transnational corporation	Type of arrangement	Amount (US$)
Joint Venture	Corning Glass Works	Joint venture to develop medical diagnostic products	
Creative Biomolecules	Stryker Corp.	Long-term agreement covering R&D and supply of human osteogenic protein	
Centocor	Hoffman La Roche	Joint venture. Roche will do clinical testing on non-human cell line-derived monoclonals. Roche will then develop and market products based on these antibodies.	
Centocor	FMC Corp.	Joint venture covering development of human cell line-derived antibodies, production of human monoclonals and development of immuno-regulatory therapeutics and diagnostics.	
Calgene and Phytogen		Joint development between two specialty bio-technology companies of herbicide-tolerant cotton varieties	
Biotechnica International	Seagram	Five-year research contract and purchase of 11 per cent equity	10 million
Biotechnica International	Uniroyal	Four-year programme on applying genetic engineering and nitrogen fixation technology to increase crop plant yields	
DNA Plant Technology	Campbell Soup	Funding of high solid tomato development in return for exclusive rights to varieties developed	
Intellicorp	Amoco Corp.	Joint venture to develop and market artificial intelligence-based software products for molecular biology	Additional 4 million for controlling interest in Intellicorp's genetic engineering software subsidiary
Nova Pharmaceutical Corp.	Celanese Corp.	Joint venture to develop drug delivery systems in Nova	Also, 10 million for 4% interest
Applied Biosystems	Rothschild Inc.	Two-year research funding through several venture capital funds	3.1 million
Imperial Biotechnology Ltd.	U.K. Dairy Industry Research Policy Committee	Three-year agreement for development of an enzymatic system for maturation of cheddar cheese	£100,000

continued

Table 10 (continued)

Research & development company or university	Transnational corporation	Type of arrangement	Amount (US$)
Calgene	Rhône Poulenc Agrochimie	Contract to develop sunflower varieties tolerant to Bromoxynil (herbicide)	
Calgene	Kemira (Japan)	Contract to develop herbicide-tolerant rapeseed and turnip rape	
Calgene	Nestle Products Technical Assistance Co.	Joint development of herbicide-tolerant soybeans for third parties	
Hybritech	Teijin Ltd. (Japan)	Ten-year joint venture to develop human monoclonals against cancer	Up to 7.5 million for three years
Cetus	Eastman Kodak	Development of *in-vitro* human diagnostics	
Immunex	Eastman Kodak	Joint venture (Immunology Ventures) to research, develop and manufacture lymphokine therapeutics	
Cold Spring Harbor Laboratory	Pioneer Hi-Bred	Five-year joint research agreement on genetic manipulation of corn	2.5 million
Amgen	Johnson & Johnson	Develop, manufacture and market erythropoietin hepatitis B vaccine and interleukin-2	
Louisiana State University	Helix International Corp.	Joint research programme (University Agrinetics) into viral diseases in animals and plant and animal improvement	
Amgen	SmithKline Beckman	Joint programme into commercializing porcine somatotropin	5 million investment by SmithKline in Amgen
Chiron Corp.	Ciba-Geigy	Joint venture to develop vaccines against infecsious diseases	
DNA Plant Technology	Du Pont	Project to develop value-added plant varieties	
Calgene	Ciba-Geigy	Agreement for Calgene to develop disease-resistant crop plants	
NeoRx Corp.	Eastman Kodak	Joint development of monoclonals for cancer treatment and diagnostics	Kodak now holds over 20 per cent of NeoRx.

continued

Table 10 (continued)

Research & development company or university	Transnational corporation	Type of arrangement	Amount (US$)
Endotronics	Celanese Corp.	T-cell adoptive immunotherapy programme	Additional 2 million in return for 120,000 shares of Endotronic.
Nova Pharmaceuticals	Celanese	Drug delivery systems joint venture	Celanese will acquire 10 million (4%) of Nova.
Monoclonal Antibodies Inc.	Alcan Laboratories	Development and Manufacture of external ocular infection detection tests..	

Sources: "Hybritech: Portrait of a Monoclonal Specialist," Bio/Technology, April 1983; "Turbulent Times for Kodak," New York Times, 13 February 1986; "Down to Earth Biotechnology," New Scientist, 25 April 1985; "Calgene, Phytogen Sign Pact on Herbicide Tolerant Cotton Seed," Genetic Engineering Letter, 24 November 1984; "Centocor: Cashing in on Serendipity," Bio/Technology, February 1985; "Calgene Strives to Lead in Plant Biotechnology," Chemical & Engineering News, 29 April 1985; "Chronicle," Bio/Technology, January, September, October and November 1985 and January, March , April, August, and November 1986; "Biotechnology Firms Record Substantial Revenue Increases," Chemical & Engineering News, 1 September 1986.

Cited in D. Dembo and W. Morehouse, Trends in Biotechnology Development and Transfer, UNIDO, Technology Trends Series No. 6, IPCT. 32 (Vienna, 19 June 1987), pp. 24-26.

Table 11. National government funding of biotechnology R&D

(millions of US dollars)

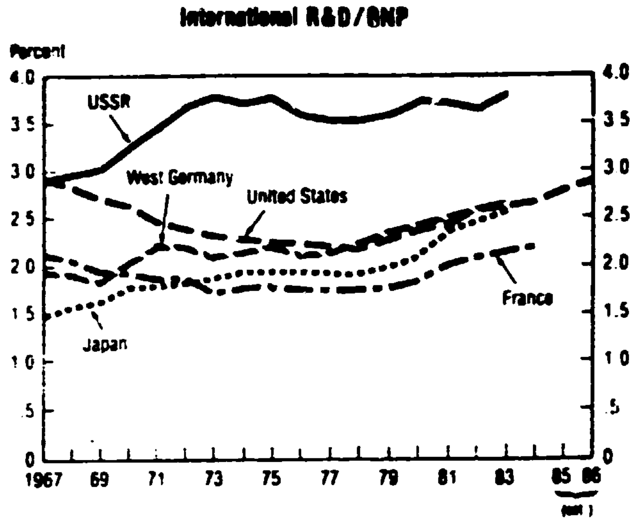
Country	1982	1986
United States	483	1,000*
Japan	200	210
France	85	...
Federal Republic of Germany	40	70
United Kingdom	15	3

Source: For 1982, U.S. Government Interagency Working Group on Competitive and Transfer Aspects of Biotechnology (1983), p. B-105; for other years, diverse sources.

Note: EEC funding forecast at 10.35 ECU over 1987-1991 period.

* billions, spread over five years

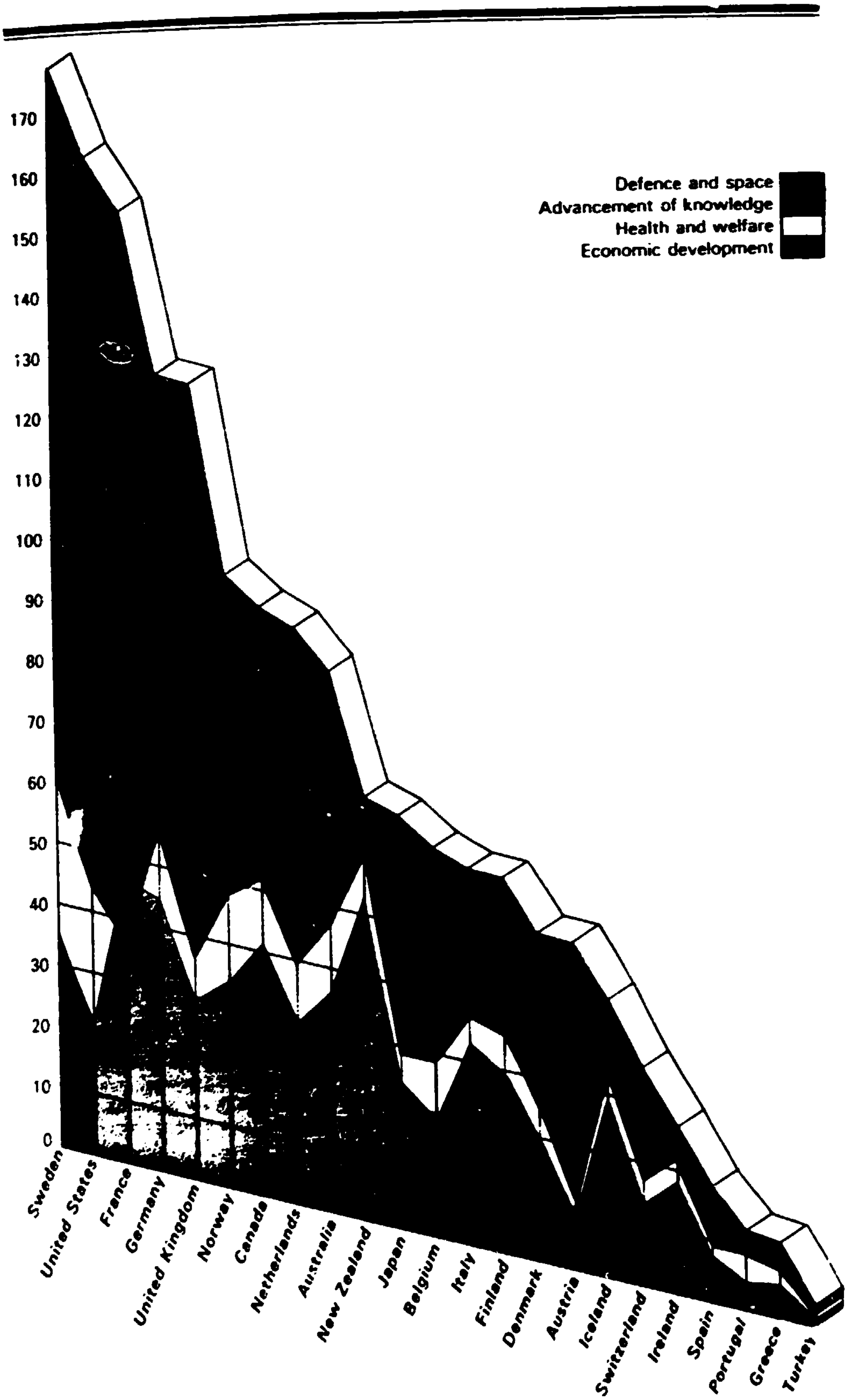
Figure I. International R&D/GNP



Source: Technical Insights, Inc., Annual Report on Research and Development (1986), p. 309.

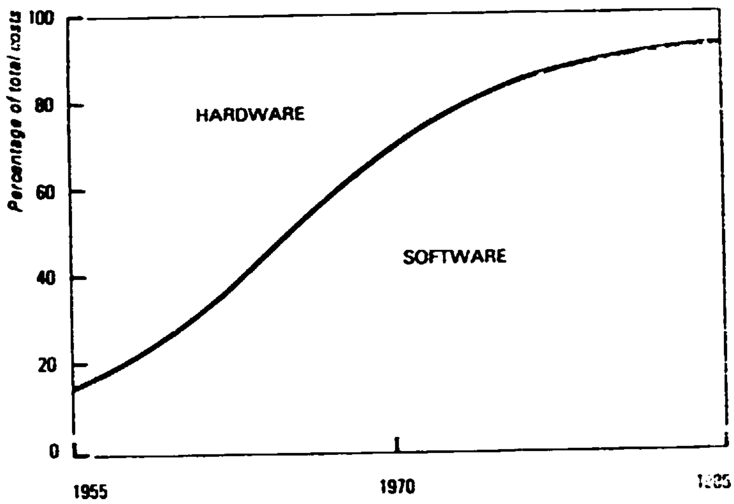
Figure 11. Per capita public R&D funding by socio-economic objectives, 1983

(in US dollars)



Source: OECD Observer, no. 138 (January 1986), p. 17.

Figure III. Share of hardware and software costs in information technology applications



Source: Computer (1983), cited in OECD, Software: An Emerging Industry (Paris, 1985), p. 20.

II. INDUSTRIAL AND TECHNOLOGY MARKET STRUCTURE

This chapter examines certain groups of technological advances characterising the present technological scene, focusing on trends in their production, the nature of firms engaged in their production and the changing nature of the industrial structure in each case. The last-mentioned aspect is intended to reflect what may be called the "technology market structure". It is important for countries and firms wishing to acquire an industrial and technological capability in any of these groups of technologies to understand the sources of production and technology, the oligopolistic or competitive nature of the market, and the nature of production and technology transfer arrangements entered into. The discussion in this chapter centres solely on these aspects of three technological advances, viz. information technology (IT), genetic engineering and biotechnology and solar photovoltaics.

At the outset, some of the problems that any new technology creates in the classification and generation of data should be pointed out. First, definitions of industrial classes lag behind changes in technologies. Defining ex ante appropriate industrial classes arising from changing technologies is impossible. Much of earlier electronics production was therefore subsumed within various electrical engineering classifications. Second, the convergence taking place, particularly that of computers with telecommunications, has made the allocation of new product groups under a particular industry group arbitrary.

For these reasons, and also because relative unit costs of different IT products are changing in a myriad ways, little is to be gained from examining shifts over time in the composition of total IT production. For example, a declining share of semiconductor production in total electronics production does not necessarily mean that semiconductors are figuring less prominently in information technology but may simply be reflecting their rapidly declining unit costs.

Likewise, there are problems in presenting production data on biotechnology and new materials particularly those attributable to new technologies.

A. Information technology: producers and users

World production in the electronics industry in 1985, excluding centrally planned economies, amounted to $485 billion, or 4.7 per cent of gross world product. By the year 2000 it is expected to account for 8 per cent. At present computers and software amount to over a third of the total. (UNIDO, Microelectronics Monitor, 18, April-June 1986, p. 11) Table 12 shows the major exporting countries of electronics products.

"Convergence" is a word that is currently in vogue, particularly in the electronics industry, where it represents the "merging of computer and telecommunications segments as more and more public networks carry combined voice and data, and as everything from local and area networks to communication satellites blur the once-clear distinctions between two businesses with disparate histories, structures and economics". (Mackintosh, 1986, pp. 105-106)

Mackintosh actually identifies a trend with more far-reaching implications. He calls it "product desegregation", of which convergence is only one example. Figure IV depicts the commonly held view of the way the electronics sector was segmented 15 years ago. There were clearly delineated subsectors: electronic components were at one end (several units with a low average unit price); large systems such as mainframe computers and telephone exchanges were at the other end (few units with a very high average unit price).

Technological change pushed the boundaries on either side of each sub-sector. Some consumer electronics products performed simpler tasks at lower prices while others did far more sophisticated tasks at much higher prices. This was reinforced on the demand side as users wanted products that were both cheaper and more complicated. Figure V illustrates how the once-distinct boundaries have begun to blur. The electronics industry of the mid-80s is more desegregated. Mackintosh forecasts a price-volume continuum of products by the 1990s (see Figure VI). Available at one end will be some microcircuits so powerful that they could be considered systems. At the other end will be some systems which, despite a still relatively high average unit price, will be produced in large numbers (i.e. standardised private-branch switching systems). It is this product continuum, rather than the simple integration of computers with telecommunications, or information technology with genetic engineering, that best embodies convergence. (Mackintosh, 1986, pp. 106-108) (1)

Table 13 presents the technological structure of the information industry showing the different levels of technological complexity and investment requirements.

1. Computers: hardware and software

Data processing capacity has grown extremely rapidly. Table 14 shows the production increase and the rise of computer stocks worldwide between 1977 and 1987. The even more rapid growth of micro- and mini-computers has been a significant development in the computer industry. These systems owe their development to improvements in components, making the 32-bit microcomputers - now ubiquitous tools on working desks - hardly distinguishable from the mainframes of the 1960s (except in terms of size and user-friendliness). In 1984 the business market for personal computers (and there has also been a growing market for home use) was $10 billion in the United States alone. (Hoffman, 1986, p. 27) The OECD cites a forecast that by 1987 the market in value terms for personal computers (less than $10,000 in 1984 dollars) will be greater than that for all other computers. (OECD, 1985, p. 21)

Software, the set of instructions that allows computers and other IT machines to perform specific functions, is the crucial factor in all IT applications. Word processors, flexible manufacturing systems (FMS), electronic fund transfer systems and transport control systems are just a few of the products dependent on software for their operation. A 1984 survey of some of the largest U.S. computer manufacturers revealed that in 1981 the average proportion of R&D expenditure devoted to software was 35 per cent; by 1985 it was expected to be 55 per cent. (OECD, 1985, p. 61) Software is becoming a more indispensable part of the package. Though not technically essential, hardware-software packages are frequently marketed as a single product.

As the hardware is standardised, it is software that becomes the distinguishing feature. For a number of reasons to be discussed subsequently, software producers include both computer manufacturers and independent software producers. The latter supply almost 60 per cent of the market. (OECD, 1985, p. 189) Customers are demanding new applications for their computer hardware, and software fills this demand. Sales of software in the United States nearly quadrupled between 1981 and 1984; by 1990 sales are expected to have quadrupled again (see Figure VII).

A similar trend is expected in Western Europe. In 1985 the region had software sales of $5 billion. Based on a forecast of an annual growth rate of 30 per cent, by 1991 sales could reach $24 billion. (Financial Times, 27 June 1986, p. I)

To understand the computer industry, one must recall a crucial feature of the industry since its beginnings in the 1950s: it has been dominated by one company - IBM. There have been a dozen or so major competitors at the hardware end, and a number of competitors have mushroomed at the software end, but a shake-out in the industry has begun. It is widely believed that by 1995, 10 (or less) major players will have remained and that the number of specialist companies, not necessarily from the mainstream computer industry, will have increased. With the convergence of computers and telecommunications, some of the big survivors may have their origins in telecommunications and general electronics. IBM and AT&T will almost certainly be among them.

Even computer companies with a turnover of more than $5 billion are anxious about their survival. Among this group are many mergers: Burroughs and Sperry (U.S.), French manufacturer Honeywell, Bull and Japan's NEC. NCR (Japan) is seeking to specialise in banking applications and Control Data (U.S.) is losing money. All these companies have to reckon with IBM since it sells about two-thirds of the world's computers, in value terms.

Software can be divided into two parts: systems software, which makes the machine work; and applications software, which takes account of the user's requirements. In the 1960s systems software was included in the price of hardware. But in 1969, the U.S. Justice Department required IBM to invoice them separately. This move was actually in the interests of the suppliers because systems software was becoming too expensive to be provided essentially free. This requirement is often cited as the beginning of a discernible software industry. Hardware manufacturers had a competitive advantage in the supply of systems software and some standard applications software (e.g., accountancy and payroll) as they were familiar with the hardware systems and had developed close links with the major users. However, the door was opened to custom-designed software, supplied by independent software houses. In 1982 hardware manufacturers controlled approximately two-thirds of the systems software market while the independents had more than 80 per cent of the applications software market. (OECD, 1985, pp. 55-56) In the late 1970s and early 1980s, the number of software houses in the United States grew at a rate of 18 to 20 per cent per annum. (Miles, 1984, p. 29)

The growth in demand for new and better programmes suddenly turned software into big business. In 1981 software was essentially a cottage industry, with sales of just $2.7 billion. Not too long afterwards, by 1984, sales had exceeded $10 billion. Several software companies became sizable corporations. For example, Management Sciences America, Inc., the largest independent software supplier, quadrupled in size between 1981 and 1984. Thousands of new companies entered this lucrative market. The world market for software is expected to increase by 30 per cent annually and could reach $150 billion in 1987 (according to another estimate, by 1991).

Until recently most software companies concentrated on a particular niche. There were three distinct markets for both mainframe and personal computers: applications software, utility software and systems control software. The computer manufacturers themselves provided the systems software, which handles basic activities such as controlling the printer and the memory. Independent software houses joined them in writing utility software, the interface between the operating system and the applications. Many other companies competed in the market for applications packages, the set of instructions telling a computer how to do specific tasks such as accounting or word processing.

These distinctions are blurring. Hardware manufacturers are strengthening their own applications software efforts on their own, or through acquisition of existing software houses, or through joint ventures with existing software houses. Software houses that used to occupy just one market niche are moving into others. Publishers and other companies outside the computer business are licensing programmes and then selling them, using their own distribution networks. One result of all this activity is an increase in mergers and acquisitions in the industry. In 1983 there were 146 acquisitions in the United States, valued at more than $1 billion. (Business Week, 27 February 1984, pp. 54-55)

Some kind of restructuring of the software industry is expected. Table 15 shows that of the top 10 independents, seven have traditionally specialised in mainframe products. Six are now starting to turn out programmes for smaller companies. And personal computer software companies see new opportunities in software for larger machines. Intense competition is expected to develop in applications software and database management programmes. The new competition in software may lead to price reductions and also increased involvement in software.

Most hardware manufacturers that responded by establishing their own software houses chose not to sell to companies with incompatible systems. It is this, together with the convergence of computers and telecommunications, that has reinforced IBM's position. Now that computers can communicate with each other, it is vital to have IBM-compatible machines. Because of IBM's leadership position, its standards became the industry's standards by default. Despite the European Commission's ruling that IBM must give its competitors sufficient warning about impending changes in its systems designs, IBM retains a technological and competitive edge. Some of these issues, most importantly the convergence of technologies and suppliers, will be explored in the following section on telecommunications.

2. Telecommunications

Telecommunications is one of the largest and fastest growing sectors in the world economy. The turnover in the sector for the EEC countries, Japan and the United States is roughly equivalent to 3 per cent of the world's GDP. This places telecommunications on a firm footing with the largest industries - motor vehicle manufacturing (2), electricity production, aerospace and petrochemicals. Despite the global recession, growth in telecommunications in recent years has averaged 8 per cent a year worldwide, and 10 per cent a year in developing countries. If this growth is sustained, telecommunications will be the largest sector, with a turnover of about 7 per cent of world GDP.

In 1982 equipment sales were worth $47 million and by 1992 are expected to double. Purchases of OECD countries now account for about 80 per cent of total sales, reflecting the uneven distribution of telecommunications infrastructure between developed and developing countries. Purchases of developing countries as a whole account for just 11 per cent of world sales. This slight figure underlines the growth potential of these as yet uncommitted markets, and suppliers of telecommunications systems are competing intensely to gain access to them. (Hobday, 1987, pp. 11-13)

The telecommunications industry is highly oligopolistic. The 10 leading corporations account for approximately 70 per cent of world sales. The largest, AT&T, established its lead through its long-standing monopoly of the U.S. market; until recently it was prohibited from competing internationally. The other market leaders all undertake international transactions, although many rely on their domestic monopoly for the bulk of their sales. Outside the largely protected markets of the OECD countries, L.M. Ericsson (Sweden), ITT (U.S.) and Siemens (FRG) have been the dominant corporations. Recently, however, Japan's NEC has entered the more unprotected markets in a major way, particularly in the developing countries.

In 1982 the U.S. Government introduced legislation making it possible for AT&T to compete for overseas orders of telecommunications equipment and to enter other areas of the IT market, which anti-trust legislation had previously prohibited. The objectives of the 1982 legislation were to stimulate competition in the face of Japanese success in the U.S. and European markets, and to encourage the introduction of new digital information services within the U.S. public and private sectors.

Governments play an extremely important role in formulating the competitive environment in which telecommunications companies operate. In OECD countries, government purchasing makes up between 60 and 85 per cent of all telecommunications sales. The service carriers are either owned or strictly controlled through postal or telecommunications administrations.

Government orders have continued to be allocated to local companies partly because of the perceived importance of a strong national supply industry and partly to ensure economies of scale in development and production. This type of government purchasing support has led to extremely high concentration ratios within countries where major producers are based.

Until recently the ranking of the top 10 to 15 telecommunications companies hardly changed, especially between 1973 and 1982. However, as Table 16 shows, by 1983 Motorola (U.S.) - a leading manufacturer of semiconductors - and IBM (U.S.) had joined the top 10 telecommunications suppliers. This is indicative of the widespread structural adjustments now occurring within the telecommunications industry, and between telecommunications and other areas of information technology. Government deregulation of telecommunications in the United States enabled IBM to compete in that market. Technological convergence has enabled other companies to gain a firmer grip on telecommunications technology.

Soaring R&D costs together with the need to achieve economies of scale have led many predominantly telecommunications firms to participate in joint ventures with other equipment makers and with providers of telecommunications services. Successive generations of Japanese firms have gained significant shares of the international IT market, intensifying the competition. Japanese firms have not yet established a stronghold in the main public switching networks but are gaining markets fast in areas such as PABX (private automatic branch exchange), transmission and peripherals. In the deregulated PABX sector, NEC already has 5 per cent of the market.

European and U.S. firms see greater export orientation as increasing both their market share and their international competitive position. European companies have entered into a wide range of commercial and technological joint ventures to improve technical co-operation within Europe, to gain access to the U.S. market, and additionally, to protect themselves against AT&T and IBM competition. Similarly, U.S. firms are hoping to gain access to European markets through joint venture arrangements. Japanese firms are also now getting involved in joint ventures with European firms as a means of selling their technology in Europe, and with American firms, which are trying to gain a foothold in the Japanese market.

The U.S. Government responded to technological change and internal pressures to open up the new value added networks (VANs) to competition by deregulating the local market. Japan has also recently agreed to open its telecommunications market to foreign competition. In Europe, Britain has taken the lead in deregulation with the privatisation of British Telecom. There are signs that several other European countries will follow. All these moves are intended to ensure the commercial orientation of telecommunications monopolies and the acceleration of the introduction of new IT services.

At the level of the individual firm, some of the major telecommunications service providers are integrating backwards into equipment production. AT&T has reached agreement with Philips (Netherlands), ICL (U.K.), Olivetti (Italy) and Ricoh (Japan) to market their products abroad. Since many service providers have had little foreign operating experience, joint ventures are one way of establishing marketing channels. Several telecommunications administrations in developing countries (e.g., Telemex in Mexico, Telebras in Brazil and NPTIC in China) are engaged in various forms of joint ventures with transnational corporations.

As for suppliers of telecommunications equipment, most of the major ones have been diversifying into other production areas of IT, such as computers, semiconductors and data processing equipment. With the erosion of the vertical market structure, which prevailed under the paradigm of electro-mechanical technologies, value added has been steadily transferred to semiconductor manufacturers. Thus, several major telecommunications equipment suppliers are attempting to increase their share of the component market. Siemens, Italtel (Italy), CIT-Alcatel (France) and Plessey (U.K.) are engaged in a joint European venture to develop VLSI chips. These types of joint ventures should be seen as diversification into other IT areas rather than as vertical integration since VLSI components are not specific to telecommunications but are intended for general IT applications.

AT&T, L.M. Ericsson, Plessey, STC (U.K.) and Siemens have all entered joint ventures or are competing independently for a share of the growing office automation and business equipment markets. Soon AT&T and IBM are expected to do battle in the personal computer market. ITT, AT&T, NEC, Northern Telecom (Canada) and Philips are preparing to challenge the dominance of Corning Glass (U.S.) in the fibre optics market. NEC is a model of a firm that is horizontally integrated across the whole range of IT products.

Conversely, firms successful in other IT products are now moving into telecommunications. The public switching market has remained relatively untouched due to high R&D thresholds, technological complexity and market saturation. However, many computer manufacturers, including IBM, ICL and Olivetti have entered the PABX market. These diversifications should be regarded as aggressive market responses to new opportunities presented by technological convergence.

A final trend worth noting is the growing international network of technical co-operation and marketing joint ventures. Not all the arrangements are successful but each contributes to the growing internationalisation of the expanding IT industry. (Hobday, 1987, pp. 15-21)

3. Semiconductors

The semiconductor industry is dominated by the United States and Japan and, to a much lesser extent, Western Europe. In 1984 global production of semiconductors was about $30 billion, of which integrated circuits (ICs) accounted for approximately $24 billion. Table 17 shows the 1980 and 1985 global division of semiconductor production according to home country of the producing firm. While the United States continued to maintain its lead, Japan was fast gaining ground. Most European chip products are outside the mainstream chip industry and produce largely for specialist markets. With the exception of Philips, all top 10 chip producers are American and Japanese firms; the five next largest European firms are all markedly smaller than the five largest American and Japanese firms. It has been argued that European chip producers are actually of sub-critical size. (Guy and Arnold, 1987, p. 13)

The importance of the semiconductor industry far exceeds the monetary value of its products since it is such a pervasive technology. A few years ago semiconductors were thought to be taking up an increasing proportion of the value of electronics products. However, this has not happened largely because the cost of producing integrated circuits has fallen. The value of semiconductors remains about 5 per cent despite the dramatically increased number of functions that have been incorporated within almost all electronic products. (Sigurdson with Tagerud, 1986, pp. 13-15)

Though telecommunications and computer companies are beginning to look upon semiconductor manufacture as a suitable case for acquisition or independent entry - a trend common to Europe, Japan and the United States - the semiconductor industry in each of these regions has different origins.

In the United States, Bell Laboratories contributed significantly to the development of semiconductor technology. However, it was Texas Instruments and Fairchild that dominated the industry during the 1950s and 1960s. Although privately owned, they received considerable government support via the military and space programmes. Anti-trust legislation explicitly excluded AT&T and IBM from entering this market. This development, together with relatively low entry costs, allowed smaller firms to break into the market.

American firms gained a valuable head start in the industry, with Japan and several European countries attempting to foster local capability through the use of trade and other barriers. This had the effect of increasing American-Japanese joint ventures and American foreign direct investment in Europe. Japan's semiconductor industry developed within integrated electronic companies. The five major producers and consumers of semiconductors in Japan (3) were involved jointly in the VLSI project sponsored by the Ministry of International Trade and Industry (MITI) between 1976 and 1980. The project sought to bring the capabilities of Japanese producers in line with their American counterparts. They were more than successful, not least because the recession of 1974-1975 forced American companies to cut back their investment programmes, thus keeping them from meeting the subsequent surge in demand. Efforts of European companies were not as successful as Japan's, partly because of a lack of venture capital and partly because of difficulties in cross-national co-operation at that time. (OECD, 1985, pp. 24-26)

U.S. semiconductor firms had established themselves by selling mass-produced chips. Their largest customers were the computer systems establishments and firms that used chips in manufacturing defense systems, control systems for robots, telecommunications equipment and other electronic devices. Much of this mass production of semiconductors was located in the low-wage countries of Asia. However, semiconductor production is being automated to improve both quality and yield (4), but whether or not this will result in a relocation back to the home country is still unclear.

ASICs (applications specific integrated circuits) are a related market that are growing in importance. The market share of this segment is forecast to grow from 8.6 per cent in 1983 to more than 20 per cent by 1991 - a growth rate far exceeding those of standard, off-the-shelf chips. The personal computer is an ideal illustration of the growth of this market. Early models of personal computers contained circuit boards packed with hundreds of chips. Today the major functions of a personal computer are controlled by as few as five ASICs. The most important impact of the growth of the ASICs market on the electronics industry has been to fundamentally change the relationship between chip suppliers and their customers. Now that many of the functions of an electronics system can be integrated onto fewer chips, and the chips can be customised to meet the requirements of specific applications, chip designers and systems designers need to work closer together. Chip producers have to disclose some of their secrets; in turn systems designers must trust chip producers with the proprietary secrets of their new products.

This need for close working relationships is an important factor behind the growing number of alliances between semiconductor and electronics companies, for example, between National Semiconductor and Xerox. U.S. companies see it as essential in their competitive battles with the Japanese. They are attempting to emulate the vertically-integrated structure of the Japanese electronics companies. (Financial Times, 18 December 1986, p. 22)

VLSI has also been a major factor behind the changing structure of the whole electronics production complex. With VLSI, hundreds of thousands of transistors are embedded in a single silicon chip. This is not simply the next step in the process of increasing power and decreasing size. Single chips produced by semiconductor manufacturers will now be able to compete in performance and speed with the large systems of chips assembled by computer firms. Thus, the traditional division of labour between semiconductor and systems assembly firms is blurring. For example, the new microcomputer developed by Hewlett Packard has as its core a single VLSI chip. The product has the power to compete with other microcomputers that are the size of refrigerators, cost four times as much and use dozens of chips.

Because of the historic division of labour in the United States between semiconductor manufacturers and systems assemblers, few companies are in a position to take full advantage of the possibilities provided by convergence.

IBM is one exception. Even though it remained committed to the production of mainframe computers, IBM has recently entered the personal computer market and semiconductor production successfully. Japanese companies are in a much stronger position to take advantage of convergence because of their system of families of firms - including firms involved in robotics, semiconductors, computers and other high technology products. (Ferguson, 1985, p. 47)

This section and the preceding two have pointed to a tendency towards increased concentration and integration in industries with previously separable areas of IT production. Figures VIII and IX illustrate these trends. Figure X depicts the new shape of the merchant IC industry.

On the subject of integration of activities, it may be noted in passing that although electronics firms and machine tools producers have so far respected the boundaries of their industries, they have integrated their activities in areas that lie on the borderline of electro-mechanical technologies. In the future machine tools manufacturers may be absorbed into the IT industrial complex. (UN/ECE, 1986, pp. 69-74)

4. Consumer electronics

Developments in the consumer electronics sector provide some good examples of trends common throughout the electronics complex - for example, the tremendous proliferation of new products based on microelectronics. Growing demand for these new products has stimulated the resurgence of an already mature industry. U.S. sales for all consumer electronics products were $16.1 billion in 1982, $20.1 billion in 1983 and $22.7 billion in 1984. (Hoffman, 1986, p. 23) The number of television receivers produced rose from 29.5 million units in 1965 to 77.7 million units in 1981. (Sinclair, 1985, p. 3)

The electrical machinery industry as a whole - including consumer electronics, heavy electrical equipment for power generation and distribution, and other electrical apparatus such as lighting equipment - contributes 6 per cent of manufacturing output in the developing countries compared with 9 per cent in the developed countries. However, electronics accounted for more than half of that output in most countries in 1980. The proportion was 60 per cent in the United States and 50 per cent in Japan. In developing countries electronics contributed as much as 80 per cent of manufacturing output in Malaysia, 75 per cent in Singapore and 68 per cent in the Republic of Korea. (UNIDO, Industry and Development, Global Report 1986, p. 87)

Table 18 illustrates, through the case of video cassette recorders, Japan's remarkable success in the production and export of consumer electronics. Japanese producers introduced many improvements in products and processes (leading to a reduction in number of components required) and the use of automatic insertion processes (leading to a reduction in lower unit costs). (Hoffman, 1986, p. 24)

The case of consumer electronics demonstrates how changing production patterns are affecting the prospects for developing countries. Until recently the assembly of consumer electronics served as a relatively accessible entry point for many developing countries into the consumer electronics market. For example, between 1975 and 1980 U.K. imports of consumer electronics grew from £179 million to £489 million, of which more than 60 per cent were imports from developing countries in Asia. (Hoffman, 1986, p. 22) These countries were dependent on Japan for components and assembly technology. Currently though, Japanese producers are changing their strategy. Fearing that increasingly protectionist North America and Western Europe will import less, Japanese firms are investing in these two regions either through cross-licensing or direct investment, instead of continuing to locate production in the low-wage Asian countries as in the past. The higher degree of production automation makes it possible for the new investments to be competitive with imports from low-wage countries. The pace of technological development is so fast that developing countries will have to develop their capabilities (as in the Republic of Korea) or continue to rely on transnational corporations if they are to remain dynamic participants in the global supply of electronic components, television sets and radios. (UNIDO, Industry and Development, Global Report 1986, p. 89)

5. IT user industries

One characteristic of information technology is its pervasiveness - its potential to be applied in all areas of human endeavour. This section examines the implications of information technology for user industries: agriculture, forestry and fisheries; primary extraction; manufacturing; private services and public services. Table 19 summarises the key IT applications in each of these five major economic sectors.

(a) Agriculture, forestry and fisheries

These industries are characterised by physical interaction with the environment, affected so far by mechanisation rather than automation. However, information technology is likely to have a major impact in two areas. First, information technology can help bring about a better understanding of the scientific base, thus enabling more efficient monitoring of pests and yields, for example. Second, information technology can assist in the sector's management, including identification of markets.

Structural changes are likely to be reflected in the continuing move towards large-scale operations to achieve economies of scale, accompanied by concentration of ownership. Information technology also allows a greater degree of integration particularly in the food processing industry, which is seeking greater control over quality and delivery dates.

Growth in productivity in the agriculture, forestry and fisheries sector has been remarkable during the past decades. In the industrialised countries "jobless growth" has been a feature of this phenomenon. In the United Kingdom, between 1953 and 1975, employment declined by 50 per cent while productivity increased by 160 per cent. Much of the productivity rise has stemmed from mechanisation, improvements in organisation and planning, and improved economies of scale. Information technology is actually peripheral to these trends, which are also now emerging in developing countries. Information technology can, however, contribute marginally. Robot tractors are already in use; experiments are under way in robot sheep shearing and animal husbandry. However, such techniques are likely to be used only in very large farm units. Systems for irrigation, crop spraying, feed regulation and produce handling are likely to be much more widely diffused.

(b) Primary extraction

This industry is also characterised by the nature of its interaction with the physical world. Likewise, the growth in its scale of operations has created a need for information manipulation techniques. Compared with the preceding sector, the primary extraction industry can probably employ information technology more effectively towards understanding the industry's scientific base. Extremely sophisticated techniques are being applied and further developed in oil and mineral exploration. Robots are beginning to be used under water and in other hostile environments.

Future uses of information technology are likely to reinforce the trend towards concentration into large-scale operations. As the scale of operations increases, information technology can shift the decision-making to major urban areas, away from the point of production. Relocating mines and wells is obviously impossible but information technology can be at the centre, co-ordinating production and scheduling transportation.

Information technology may lead to higher productivity in the primary extraction industry. But shifting patterns of supply and demand, and political forces, affect competitiveness more. For example, the recent fall in oil prices has led to a shakeout in the industry. Many smaller, independent companies that grew in the late 1970s have not been able to survive. They have either merged with other small companies or have sold out to the majors. In cases where they have had access to capital, they have diversified into totally new business areas.

(c) Private services

This includes all services usually provided by the private sector: banking and finance, insurance, retailing and distribution, office services, hotels and catering, and leisure. Many of these services involve a high level of information activity. Banking, for example, is essentially a process of information storage, retrieval, manipulation and communication. Retailing and distribution, even though concerned with the movement of physical goods, relies on effective management of information about stockholding and delivery requirements.

The potential of information technology to provide a wide range of services tailored to individual needs is widely believed as leading towards decentralised and more competitive private services. Firms supplying services such as home banking and shopping, accountancy and share dealing are expected to proliferate. Even though the number of firms providing specialised services may rise dramatically, central financial structures will most likely use information technology to maintain their hold over the financial system. This does raise problems of social participation, privacy and security, which must be addressed.

Indicators are contradictory on the future structure of private services. Small, specialist firms may be flexible enough to use information technology to provide almost tailor-made services. On the other hand, large organisations such as banks and insurance companies could also use information technology to reinforce power and control, at the same time exploiting the potential of the technology to provide a wide range of services. Again, a structure with small, decentralised, largely autonomous units co-ordinated from the centre should be considered.

More difficult to gauge are the implications of information technology on the productivity of service sectors. Office productivity cannot be measured in the same way as manufacturing productivity. For example, the ability of a typist to produce an extra 10 pages per hour using a word processor is not necessarily reflective of an increase in productivity. Indeed, many argue that information technology has facilitated the proliferation of drafts. What information technology does offer is an opportunity to re-organise office systems thoroughly.

The situation in banks and retailing organisations is different, many of of the systems having been automated years ago. Information technology does present an opportunity to replace labour-intensive operations. The major issue concerns the proliferation of other organisations offering competing services.

In the leisure industries, information technology can facilitate hotel bookings, scheduling and security. Overall, however, the impact of information technology on the structure of the increasingly concentrated private services industry remains to be seen.

(d) Public services

The areas that fall under the definition of public services are often the outcome of a political process and therefore vary among countries. But the sector frequently includes the various administrative functions of the civil service, education, health, social welfare, police and other community services. The IT applications in public services are similar to those in private services: integrated office automation, database systems and communications networks.

Considerable scope exists for improving the flow and the speed of access of information within the public sector. For example, social benefits systems can be computerized. Databases can be linked with common users, although this raises still unresolved issues of privacy and civil liberties. To date, relatively few linkages exist. Information technology makes possible the provision of much more decentralised services, operating with local autonomy but connected to a central network. All this may be technically feasible, but questions around political and bureaucratic control and authority have yet to be resolved.

Competitiveness in the sector is a difficult issue by virtue of the underlying concept of public services. Nonetheless, in recent years many governments have been wanting to introduce the accounting criteria of private services into the public sector and to open the public sector to private competition. Information technology can improve productivity in the administration and management of delivery of these services. Even more fundamental is the contribution that information technology can make towards innovative and more widely accessible education and training. (Bessant and others, 1985, pp. 29-47)

(e) Manufacturing

The pace of introduction of information technology in manufacturing has been studied in detail in certain countries. The following comparison between France, the FRG and the United Kingdom will be of interest. (Northcott and others, 1985)

Britain

Britain is slightly behind the FRG in the percentage of factories using microelectronics in their production processes and further behind in the percentage with applications in the products themselves, but ahead of France in both. Compared with the FRG, Britain makes less use of CNC (computer-numerically controlled) machine tools and robots, appears to have fewer professional engineers with microelectronics expertise and sends fewer people on training courses. However, Britain appears to be relatively strong in some areas such as the electrical engineering and food industries and in the use of semicustom chips, and to have fewer difficulties with trade unions than the other countries, but British industry has greater problems than the others in raising finance for development and in the general economic situation.

Federal Republic of Germany

The FRG has slightly more factories than the other two countries using microelectronics in their production processes and is further ahead in the proportion with applications in the products themselves, although the rate of increase in the proportion using microelectronics appears to have slowed down in recent years. The FRG is particularly strong, relative to the other two countries, in the mechanical engineering and printing industries and in the numbers of microelectronics engineers available (although more are wanted) and in the widespread use of training courses. It has higher rates of use of CAD (computer-aided design) and CNC machine tools and robots, but also more widespread problems with software, sensors and chips (although these may reflect not backwardness but a greater use of the more advanced and difficult systems). Confidence in being ahead of competitors in Europe is high and overall performance is helped by an industrial structure that is strong in the industries with the greatest scope for applications.

France

France is behind Britain and still more behind the FRG in the percentage of factories using microelectronics, particularly in products, but does not in general appear to be behind Britain in the kinds of equipment used or the numbers of microelectronics engineers available. There are some areas of particular strength such as the vehicles industry, and the larger factories have rates of use not very different from Britain or the FRG. Overall performance is impaired, however, by a less favourable industrial structure than in the other two countries and a higher proportion of small factories with low rates of use.

Extent of use

In the factories in the survey samples, the differences in the proportions of users in the three countries is not great - 66 per cent in the FRG, 65 per cent in Britain and 61 per cent in France. Nearly all these factories are using microelectronics in production processes, but in each country the proportion with applications in products is much smaller - 20 per cent in the FRG, 16 per cent in Britain and 13 per cent in France.

If allowance is made for the fact that in industry as a whole there is a far higher proportion of small factories than in the samples used for the surveys (and the small ones tend to have lower rates of use), it can be calculated that in all the factories employing 20 or more people, microelectronics is being used by only 51 per cent in the FRG, 47 per cent in Britain and 38 per cent in France. Again, nearly all these factories have applications in their processes but the proportions with applications in their products are much smaller and the differences between the countries greater - 13 per cent in the FRG, 10 per cent in Britain and 6 per cent in France.

The factories using microelectronics account for about three-quarters of total manufacturing employment in Britain and the FRG and nearly two-thirds in France.

In all three countries, applications in products are heavily concentrated in electrical and instrument engineering (where the United Kingdom has the highest percentage of users), in mechanical engineering (where the FRG has the highest percentage of users) and in vehicles (where France has the highest percentage of users). In applications in processes where the differences between industries are less extreme, there are particularly high percentages of users in food in the United Kingdom, in printing in the FRG and in vehicles in France.

It is interesting in this context to compare the introduction of information services in the United States. It is found that the expenditure on information services as a percentage of revenue is highest in banking and finance (4.5 per cent), followed by electronics (3.7 per cent), industrial and automobile sectors (2.7 per cent), insurance (1.7 per cent); process industries (1.6 per cent) and food and beverage (1.6 per cent). (Datamation, 1 September 1987)

The implications of information technology for manufacturing are still unclear, with the situation changing constantly and with a number of contradictory forces at work. Small technology-based firms may increase; they are economically viable as information technology would have improved the production economies of small-batch manufacturing. In addition, small firms are better able to respond quickly to changing circumstances, to develop new ideas and to provide local services to large companies and communities. On the other hand, information technology may simply reinforce the advantages held by large firms. Whereas production of small batches has been cheaper to sub-contract, the emergence of flexible manufacturing systems will allow economically viable in-house production. Furthermore, the benefits offered by CIM (computer-integrated manufacturing) techniques may only be realised to the fullest in large-scale operations.

Scale constraints have been cited as a major obstacle to industrialisation in developing countries. Increasing competitive pressures in domestic and world markets have stimulated efforts in many industries to gain the perceived advantages of large plant size through building progressively larger operating units. A tendency towards industrial concentration in both industrialised and developing countries has been apparent in manufacturing, particularly in chemicals, steel and automobiles as well as in power generation, mining and agriculture. At the same time, the perceived disadvantages of concentration and size have intensified the search for technological solutions, which have allowed profitable production at lower levels. However, flexible manufacturing systems may be more applicable to engineering industries than to others.

Even the highly automated, mass production industries are concerned that bigger may not be best. The maximum potential of economies of scale can be reached only if the facilities are operated at high levels of capacity utilisation over a long period. This has not been easy to achieve due to fluctuations in demand over the course of the business cycle, changes in consumer preferences regarding design and product mix, changes in the relative prices of inputs, and variations in their availability and quality. There has long been a need - one that is beginning to be met - for flexible systems of production. Information technology can lead to changes in the organisation of production, and both biotechnology and new materials have substantial implications for relative factor prices. Thus the impact of the new technologies goes much further than simply permitting down-scaling.

It may be that size loses its importance as a factor in determining productivity, and that the flexibility that economic agents are able to achieve with the new systems may become far more significant. Physical production alone is not the only consideration. While the optimal scale of production may decrease because of IT-based economies of scope, the optimal scale of other operations, including marketing and administration, may increase with the introduction of information technology. Thus, large firms may be able to set up effective barriers of entry to small firms through using information technology to exercise greater control over their markets. Information technology can be used to improve communications between geographically disparate locations. Another option would be for future industrial entities to be made up of a large number of small plants, each exercising a high degree of local autonomy but receiving the benefits of centralised R&D, marketing and financial services.

Users-turned-manufacturers are another trend. Some major consumers of the new technologies are profiting from their experience in information technology by offering their honed skills elsewhere. Automobile producers, early users of robotics and other forms of factory automation, are now among the major suppliers of this form of technology.

Both small and large firms may continue to have a future, with large firms retaining responsibility for large-scale production and small firms providing the flexibility required to supply local and specialist markets. In line with current trends, the absolute number of firms will continue to decline; simultaneously, the number of divisions within firms will increase.

Increased internationalisation is another feature of information technology although the concentration pattern throughout the world and within regions may change. For example, in Norway the relatively small number of small-scale enterprises find it difficult to compete due to problems in achieving economies of scale and problems of access to resources. They can use information technology to improve their competitiveness and productivity at firm level, and to enable them to share centralised R&D and marketing facilities. The production system can thus be tailored to meet the needs of the community. Japan, on othe other hand, has different circumstances. It needs to locate production away from centres of population to relieve problems created by pollution and space constraints. This is one reason why the Japanese have pushed forward the development of unmanned factories and methods of production that function effectively without large inventories of component parts.

The location of decision-taking and control may also shift. Many large corporations are decentralising production because of its advantages while simultaneously concentrating central resources such as marketing and finance. Access to communications is likely to become more essential than advantages of location. Thus, corporate headquarters could continue to move away from large cities; consequently, policies promoting particular regions could take on increasing importance.

Information technology will become crucial in determining patterns of international competitiveness, not only because of its potential to reduce spending on other production factors, but primarily because of improvements in product and process performance. Those who fail to make use of information technology will be operating at a major disadvantage. Concern over this issue is growing in many countries.

The diffusion of information technology in the production process raises a number of issues: the domination of the supply of information technology by a few large, integrated firms, which will set the technical standards; the optimum scale, product mix and production location; and the decision to either purchase information services or to provide them for oneself. For indeed, while permitting the rapid and accurate transmission of information, information technology also opens up possibilities of creating a market for it, supplying only what others are prepared to pay for and selling it to the highest bidder. Clearly, the future market structures of particular industries in certain countries depend in large part on the history of each case and the policies adopted now and in the future.

6. Changing location of production of information technology

Changes in the geographic location of production have been taking place at four different levels: (Ernst, 1983, pp. 148-155)

(a) locational shifts among the major OECD countries;

(b) locational shifts from the cent: to the periphery within the OECD;

(c) new patterns of investment in the export-oriented countries of Asia such as Hong Kong, Malaysia, Republic of Korea, Singapore and in the Province of Taiwan; and,

(d) relocation from these countries to new offshore locations such as Bangladesh, China, the Philippines, Sri Lanka and the Caribbean.

As mentioned earlier, Japanese and West European firms are investing in the United States because it continues to be an expanding and attractive market; also, U.S. protectionist moves are leading foreign firms to locate there so as to secure their market share. Similar pressures are motivating Japanese firms to locate to Western Europe, particularly to Ireland and peripheral regions of the United Kingdom such as Scotland and Wales. Governments of some of these economically depressed areas are trying to attract foreign investment in high technology to secure jobs and to gain access to technology. In fact Western Europe is predicted to be the most important growth market for integrated circuits - if only because it has so far lagged behind Japan and the United States.

Future markets are also emerging outside the OECD, notably in the Association of South-East Asian Nations (ASEAN) countries, the Gulf area, Brazil, China and India. Automated production methods make it possible for production in high-wage countries to compete with that in low-wage countries. However, being located close to markets still holds its advantages and pressures are building towards vertical integration within the electronics industry. Thus, countries with both an electronics production industry and a user industry have more potentially promising markets. The subject requires constant review as fast-moving changes and countervailing tendencies make future developments difficult to predict.

7. Future trends

What does the future of electronics production look like and what are the implications for world trade? Mackintosh (1986, pp. 95-99) derives projections, in 1985 US dollars, for production and markets in Japan, Western Europe and the United States. Figure XI shows that Japan's IT production almost approaches the U.S. level despite a 2:1 population ratio in favour of the United States. By the year 2006 the production level in both countries is estimated to have evened out at about $570 billion each.

Even more remarkable is Japan's predicted huge IT trade surplus. A Japanese surplus of $194 billion may seem improbable today, but then again the thought in 1970 of a $25 billion surplus in 1983 would have seemed absurd.

Not shown in Figure XI is another calculation by Mackintosh that by 1990 the "rest of the world" will produce about $120 billion worth of electronics goods but will buy about $200 billion worth.

B. Biotechnology

People have long been combining substances in order to provoke a chemical reaction. In terms of volume, biotechnology industries based on water treatment and purification form the largest sector, followed by beer and spirits, dairy products, yeast, organic acids and antibiotics. The impact of modern biotechnology lies in the creation of new products and processes and in the upgrading of existing and traditional processes over a wide range of industries such as food processing, chemicals and pharmaceuticals, energy and waste treatment.

Tables 20 to 23 provide different forecasts made in 1981 and 1982 concerning the market for biotechnology and the products expected to be commercialised within the time horizons of 5, 10 and 15 years. The forecasts have generally proved to be too optimistic in view of the problems connected with the scaling-up and the time taken to get the necessary regulatory approvals. However, progress in plant genetics seems to have accelerated. One report on the potential market for agribusiness applications of genetic engineering puts the figure at $50 billion to $100 billion annually for agricultural applications alone by 1996. Predictions for biotechnology in general continue to be optimistic. A report from the Long-Term Credit Bank in Japan suggests that worldwide markets for biotechnology-based products may be as high as $94.2 billion by the turn of the century.

A survey of companies involved in biotechnology has identified 1,036 firms. Of this total, 45 per cent or 469 were U.S.-based. The United Kingdom accounted for 29 per cent or [illegible] firms, Japan for 9 per cent or 92 firms, the FRG and Italy for 22 firms each, France for 20, and Belgium, Denmark, Ireland, the Netherlands, Spain and Sweden for 115 firms. Of the remaining 66 firms, developing countries accounted for 20 (UNCTC, 1987) of which the Province of Taiwan accounted for 11, India and the Republic of Korea for two each, and one each for Brazil, Egypt, Mexico, Pakistan and the People's Republic of China. Another 38 firms were based in the centrally planned economy countries of Eastern Europe, mostly in Poland. The rest were scattered around the world.

Most of the new research in biotechnology started with small companies, at least in the United States. These sought to finance R&D through different measures such as venture capital, public stock offerings, funding by transnational corporations (TNCs) and government support. As the practical problems of commercialisation became better known, the position of large, more established companies strengthened. Though there has been some thinning out among the small new biotechnology companies, many have survived and continue to play an important role.

The situation has been somewhat different in Japan and Europe. The approximately 200 companies in Japan that are involved heavily in biotechnology are mostly major corporations such as Ajinomoto and Mitsubishi Chemical Industries. This is also true for the FRG where it is the largest TNCs such as Hoechst and Bayer that are increasing their involvement in biotechnology and where there are virtually no venture capital biotechnology firms. In most other OECD countries, biotechnology is being developed by both new venture capital firms and established TNCs.

Out of the 500 largest U.S.-based companies listed in <u>Fortune</u> magazine, at least 83 have biotechnology-related activities. (UNCTC, 1987) Among non-U.S. based firms, out of the 500 largest also listed in <u>Fortune</u>, at least

62 have biotechnology-related activities; 22 of these firms are based in the United Kingdom, 19 in Japan, six in the FRG, four each in France, the Netherlands and Switzerland, and one each in Belgium, Italy and Panama.

Inter-firm arrangements take different forms. Japan and Europe have begun investing in some of the smaller American companies in order to gain access to the latest technology. Alternatively, these smaller companies may attempt production and marketing themselves, at least in their home countries, and arrange with other companies, usually TNCs, for marketing abroad. Typically, under such an arrangement, an American company might license production and/or marketing to a Japanese TNC for marketing in Japan or other Asian countries and retain North American rights. A second or even third TNC might also have rights to other geographic areas. Transnational corporations, of course, have well established production and marketing systems as well as departments to handle regulatory hurdles for their traditional product lines that may also be utilized for biotechnology products.

A third and more unusual approach - which has already been arranged in at least one case - is for a larger corporation to license a biotechnology company to do marketing and take care of regulatory problems. In such a case, it is the ability of a smaller company to focus its energies on one product or product line, and to develop a marketing system specific to that line, that is desired by the larger corporation.

A survey of 50 enterprise-level agreements for international transfer of technology revealed the following (5). In a majority of them, Japan figured as the recipient and the United States as the transferor, with the FRG, Italy, Sweden, Switzerland and the United Kingdom also involved. In one instance a firm in Malaysia entered into an agreement with a research company in the United States in the field of plant genetics. The products involved in these transfers were monoclonal antibodies, interferons and, to a lesser extent, hepatitis-B vaccine and insulin. The mechanisms used included subsidiaries, equity investment, joint ventures, licensing and other agreements. The objectives of joint ventures covered joint R&D, joint development involving complementary inputs from the two parties and marketing. Other agreements were concerned with funding R&D in exchange for access to technology or rights to later production and marketing; research co-operation; exchange of clinical test drug technology; marketing rights within or outside a country; agency arrangements; and supplies of commercial quantities of biochemicals. In one case, there was a tie-up between an electronics firm specialising in the application of microelectronics to biotechnology and a trading company.

Table 24 documents illustratively the variety of inter-firm production and marketing arrangments that have been made in recent years.

It will probably be some time before any sort of equilibrium is reached in the emerging biotechnology industry. While plenty of risk capital remains, there is unlikely to be enough to allow all the companies currently in business to follow through to the commercialisation phase. Mergers and acquisitions are likely to become increasingly prevalent in the next few years and the general expectation is that the number of companies competing worldwide in any one market segment will be far small smaller than the present number. (Zimmerman, in UNIDO, Genetic Engineering and Biotechnology Monitor, February 1984, p. 21)

The emerging picture also tends to show the broad-banding of TNC interests over several sectors related to biotechnology. Thus, food processing, chemical and oil TNCs have begun to invest in biotechnology initially to secure their strategic interests in particular production lines, but their interest is likely to spread over other production lines as well. Trends of this kind are also evident in seeds and agribusiness as a whole; several TNCs, particularly in the chemical field, are taking over seed companies or are controlling the seeds trade.

Notwithstanding the fact that most of the movement in biotechnology is among industrialised countries, transnational corporations based in industrialised countries do have a number of activities involving biotechnology in developing countries. TNCs have numerous manufacturing and marketing operations in developing countries in industrial sectors such as pharmaceuticals and chemicals where the potential for biotechnology is substantial. However, because very little biotechnology - certainly based on the most advanced techniques - has actually been commercialised, so far there have been relatively few TNC operations involving biotechnology of this character under way in developing countries.

Clearly, however, if present trends continue, more and more industrial processes of TNCs in pharmaceuticals, chemicals and other fields will become biotechnology-based. As this occurs, there will be substantial TNC marketing and probably manufacturing operations in developing countries in the future. But even now several aspects of TNC operations in biotechnology do involve developing countries.

The pharmaceutical industry is one key sector where TNCs that are assuming active R&D roles in biotechnology already occupy a major position in many developing countries (6). As these companies begin to develop and market products in their home countries and in other industrialised countries based on biotechnology generally and on genetic engineering more specifically, these products will begin to find their way into developing countries as well.

Pharmaceutical products based on biotechnology will not only be marketed in developing countries but will also be tested in these countries even before they are marketed. Indeed, such tests are already under way. For example, China has a joint venture with Switzerland's Biogen for the marketing and production of gamma interferon as well as an agreement with Biogen to supply the drug for clinical trials of cancer patients in Chinese hospitals. (Dembo and Morehouse, 1987, p. 81)

One existing path for TNC involvement in developing countries in biotechnology is through the acquisition of marketing rights for all of Asia by Japanese TNCs from North American biotechnology R&D and venture capital firms. For example, Genentech in the United States has contracts with Japan's Toray Industries, Inc. and Dauchi Seiyaku Co. to market gamma-type interferon in Asia. Biogen has an agreement with Shinogi & Co. for the same substance, giving the Japanese company marketing rights in exchange for royalties. A similar agreement exists between Biogen and Japan's Suntory, Ltd. for a cancer drug. (Dembo and Morehouse, 1987, p. 80) Genentech has an agreement with three other companies for marketing tissue plasminogen activator, an anti-clotting agent. Genentech retains marketing rights in North America, Boehringer Ingelheim International has marketing rights in Europe, the Middle East, South America and parts of Australia, while Mitsubishi Chemical Industries and Kyaua Hakko Kogyo will market the agent in Japan. (Dembo and Morehouse, 1987, p. 81)

Agriculture, particulary the seed sector, is another major area closely related to biotechnology where there is TNC involvement in developing countries. According to a recent study on the seed industry by Teweles, a major broker of seed companies, the U.S. seed industry is already a $5 billion annual market and is expected to grow to $11.8 billion annually by the end of the century due to advances in genetic manipulation techniques. (Business Week, 11 June 1984, p. 59) TNCs are getting more actively involved not only in vegetable seeds but seeds for cereals and other food grains as well. One obvious approach to marketing new varieties of seeds is through acquisition of existing seed companies. Thus, a company based on advanced biotechnology like the Agrigenetics Corporation in Colorado has purchased over 10 seed companies since 1975. The initial thrust has been directed towards industrialised country markets but more recently attention has turned towards developing country markets as well.

Large numbers of seed companies have been acquired in recent years by transnational corporations, particularly pharmaceutical and petrochemical companies. According to one recent study, substantial segments of the developing country vegetable seed market are already in TNC hands. Suttons of U.S.A. (owned by Cardo), Ohlsenn Enke of Denmark (owned by Svalof of Sweden), Daehenfeld of Denmark, and Zaadunie of the Netherlands (owned by Sandoz, the Swiss pharmaceutical TNC) are among the principal suppliers of vegetable seeds to Africa and Western Asia. In Latin America and the Philippines, vegetable seed is marketed by American companies like Dessert Seeds (owned by Atlantic-Richfield, the petroleum company) and Ferry-Morse (once owned by Purex and now controlled by Limagrain of France). (Dembo and Morehouse, 1987, p. 82)

There are various other seed-related activities in developing countries involving TNCs and their subsidiaries. For example, a Cardo subsidiary, Hilleshog, is working with Swedish Match to breed Acacia mangium trees for the Philippines. Campbell Soup, a U.S. food processing company, has linked up with an American genetic engineering company and Brazilian interests to breed new tomatoes in Brazil. Among vegetable varieties being grown in Kenya are cabbages from Ohlsenn, cauliflower and carrots from Dutch and American subsidiaries of Sandoz, and lettuce from ARCO's seed subsidiary. (Dembo and Morehouse, 1987, p. 82)

Biotechnology applications in agriculture offer a number of opportunities to TNCs. Perhaps most important is the ability, through biotechnology, to link the use of fertilizers and pesticides to new varieties of seeds. Thus, it is possible to develop seeds that require increased applications of certain chemicals to receive the benefits of improved yields and stress tolerance. Through seeds with such characteristics, TNCs can build a market for other agricultural inputs that they manufacture and market. In a similar manner, food TNCs are interested in seed companies because of their ability to develop and market new varieties of seeds that will produce not only greater yields but also products better adapted to commercial harvesting, storage, transportation and preparation.

The most crucial distinction between the Green Revolution and the "Bio-revolution" is the fundamentally private character of the latter in comparison with the fact that the former was based almost exclusively on technology developed in the public domain. At a minimum, researchers interested in crop improvement for developing country contexts will have to contend with a fundamentally different milieu of plant variety protection and the utilisation of patent systems to restrict access to new processes and to genetically engineered proprietary molecules. (Kenney and Buffel, 1985) Many of the products that may be displaced by industrial tissue culture originate in developing countries, resulting in progressive displacements of developing country exports of those products. Similar displacements could occur by other technological developments such as high fructose corn syprup and conversion of palm to cocoa oil.

C. Solar photovoltaics

The international flow of photovoltaic technology has been considerably influenced by the dominant conversion technology and by the expected market penetration. Photovoltaic technology has gone through three partially overlapping generations: single-crystal, polycrystal and amorphous cells. These three generations have not only shaped the structure of the industry but have also influenced the patterns of technology transfer. In the first place, the fact that the technology has been in a state of constant flux has reduced the widespread diffusion of process know-how. Secondly, the high-process control associated with ingot-growing made it difficult for new firms to enter the market or for the technology to be quickly diffused. Thirdly, the uncertainties surrounding the competitiveness of photovoltaics, coupled with the rapid rate of technical change, reduced its rate of diffusion and the flow of process technology as well.

Because of these factors, the flow of photovoltaics technology has been mostly among the United States, Europe and Japan. The transfer of photovoltaic technology to the developing countries has been restricted either to assembly facilities or to near-obsolete single-crystal cells. In nearly all the known cases of technology transfer, the flow has been mainly turnkey plants with very little transfer of know-how. This is because - as has been said - the technology itself is in constant flux; but in addition, much of the R&D is conducted at the point of origin or in universities and government centres. The shipment of plants has therefore been usually to enter a specific market as well as to reduce module assembly costs. (Juma, 1987, p. 24)

While assembly plants are being set up based on single crystal cells, other firms are extending their international operations with amorphous silicon technology in the belief that such cells are likely to dominate the market in the future. Yet other firms believe that the mass production of amorphous cells is just starting and that there is room for coexistence among different cell types on the market. Moreover, amorphous cells themselves are going to undergo efficiency- and process-related changes.

It is notable that the shift to amorphous cells outside Japan has been pioneered by emerging small- and medium-sized firms. The decision by firms to enter the market with plants based on new conversion materials illustrates the uncertainties surrounding the sources of innovation and position of firms in the market structure. The late 1970s and early 1980s saw the rapid emergence of subsidiaries of oil majors.

The commercialisation of photovoltaics has been dominated by large oil, electronics and electrical companies, which have long experience in the management of new technologies. The shift towards amorphous cells provides these corporations with the opportunity to complete the vertical integration of their photovoltaic activities. With single-crystal technology, photovoltaic producers used to be dependent on the supply of single crystal ingots from only three companies in the world: Wacker (FRG), SEMIC (U.S.) and Pragma (Italy). This oligopoly was broken up with the shift to polycrystalline material, permitting the entry of new materials producers. This has been extended even further with the shift to amorphous cells. Already the industry has experienced takeovers aimed specifically at acquiring capability in amorphous technology.

The uncertainty that current amorphous materials will continue to dominate the market, even in the medium term, has influenced the availability of raw materials for cell manufacture. The industry is presently dependent on residual crystalline silicon produced for the electronics industry. Only 3 per cent of the silicon produced in 1985 was applied to photovoltaic production. Shortages of materials are a possibility as the electronics industry is not willing to invest in additional ingot products at prices lower than can be obtained from the electronics industry. The rise of amorphous cells has been a disincentive to the expansion of single crystal silicon production. High production costs are partly responsible for current high photovoltaic costs. Responses to potential shortages include using rejects from the silicon produced for the electronics industry. Large investments in single crystal silicon material production is unlikely, given its declining share in the volume of module shipments.

Much of the technology flow in the 1980s has been between European and U.S. firms. This flow was associated with trans-Atlantic corporate links established in the late 1970s, allowing U.S. firms access to developing country markets through traditional links with former colonies. However, the location of productive facilities in the developing countries to take advantage of cheap labour has formed part of the strategy of some firms. So far only a case in Singapore has been noted. There are numerous proposals that have so far not been implemented. In the meantime, firms are emerging that tend to specialise in the export of productive facilities to the developing countries.

The actual worldwide shipments of photovoltaics, which up to 1984 had been increasing, now appear to be stagnant. It has been clear to the industry and its watchers that the earlier projections of the growth of markets for solar photovoltaics have been too optimistic. Long-term forecasts for the year 2000 and beyond do continue to be optimistic, particularly because of the rapidly increasing conversion efficiencies (from 1 to 2 percent in 1976 to 11 to 12 per cent in 1985).

The share of the United States, which was the dominant supplier of photovoltaic modules, has been dropping over time. In 1982, the United States accounted for 61.2 per cent of world module shipment. This dropped to 50.4 per cent in 1983, 46.8 percent in 1984, 33 per cent in 1985, and 27.2 per cent in 1986. At the same time, Japan's share has been rising steadily from 18.4 per cent in 1982 to 23 per cent in 1983, 35.6 per cent in 1984, 45 per cent in 1985 and 48.8 per cent in 1986. European shipments have dropped from 18.2 per cent in 1982 to 14.4 per cent in 1984, 16 per cent in 1985 and 15.7 per cent in 1986. The pattern of technological change and public sector participation have influenced these developments. Japan was able to increase its share of the world market largely because of its use of amorphous cells in consumer electronic products such as calculators and watches. (Juma, 1987, pp. 16-24)

The output of developing countries has only changed from a minuscule 0.2 unit mW in 1983 to 0.70 MW in 1984. (Juma, 1987, p. 22) The largest growth rate appears to have been recorded in India while the rest of developing country shipments is acccounted for by Brazil and Singapore, which have assembly facilities. Saudi Arabia has set up a single custom module plant aimed at supplying local and regional markets. At the same time, the developing countries have remained targets of photovoltaic commercialisation despite the disappointing sales in the last five years. The EEC is a major supplier of modules to these countries as part of its aid programmes. Individual countries such as France and Italy ship over half of their photovoltaic output to developing countries, mainly to Africa.

The initial optimism over assembly plants in developing countries was based on the view that since 50 per cent of module production costs went to BOS (Balance of System) components, their assembly in the developing countries, using cheap labour, would be possible. Moreover, reductions in cell costs would increase the share of BOS components that would have been partially standardised and would not likely undergo any major cost-reducing changes. This view was also supported by the assumption that the developing countries would be a major market for photovoltaic systems, especially in water pumping and rural electrification. Such assembly plants have so far not been set up on scales previously envisaged. One reason for the slow transfer of production facilities to the developing countries is the rapid rate of innovation in conversion materials, making photovoltaic process technologies near-obsolete at any one moment. The possibilities for selected assembly sites in the developing countries still exist but will have to await the emergence of dominant conversion materials.

However, it appears that some firms are interested in automated production and will most likely consider setting up production facilities in the industrialised countries to take advantage of advances in automation and local photovoltaic markets. Firms such as Energy Conversion Devices (U.S.) are already adopting Japanese-type automated production, thereby pre-empting the need for cheap labour. This development is linked with the fact that photovoltaic sales are growing faster in the industrialised countries than in the developing countries. It appears therefore that the rate of technology flow to the developing countries is likely to be slower than originally projected. This may change as access to automated production technology is uneven, including among industrialised country firms, some of which may use the cheap labour as a basis for competition. Moreover, the need to have access to specific developing country markets may lead to the establishment of labour-based production facilities in those economies.

Notes

(1) This sort of classification can be extended to biotechnology, although it is still a clearly segregated product market. Animal feed, water purification and ethanol are currently at the high-volume, low-value end, whereas antibiotics, enzymes and vitamins are at the low-volume, high-value end. Food products, yeast and polymers, among others, are somewhere in between. Whether a product continuum will emerge, analogous to that described for electronics products, remains to be seen.

(2) The production of passenger cars declined by 15 per cent between 1979 and 1982, commercial vehicles by 18 per cent over the same period.

(3) Fujitsu, Hitachi, Toshiba, Mitsubishi and NEC.

(4) As a result of the automation of semiconductor production, there is a fast-growing market for relevant equipment, which still falls considerably short of demand. The expansion of this market is likely to be followed by a period of consolidation based on takeovers and mergers - similar to the one occurring in the semiconductor industry itself.

(5) Compiled from: Biobusiness World Data Base. Draft report by U.S. Government Working Group on Competitive and Transfer Aspects of Biotechnology (Wash., D.C., McGraw Hill, 1983).

(6) For data on TNCs in the pharmaceutical industry in developing countries, see United Nations Centre on Transnational Corporations, Transnational Corporations in the Pharmaceutical Industry of Developing Countries: A Technical Paper (New York: United Nations, 1983).

Table 12. Major exporters of electronics products

(billions of US dollars)

	1979	1983	1984	1985
Developed countries				
Japan	13.77	26.78	35.50	36.26
United States	14.32	23.09	27.29	26.49
Germany, Fed. Rep. of	7.60	8.56	9.25	10.72
United Kingdom	4.75	5.90	7.34	8.77
France	3.96	4.51	5.02	5.86
Netherlands	2.93	3.00	3.55	3.67
Canada	1.31	2.44	3.41	3.47
Italy	2.01	2.51	2.82	3.62
Ireland	0.51	1.45	1.99	2.28
Sweden	1.58	1.76	1.85	2.24
Newly industrialising countries				
Taiwan Province	2.15	3.23	4.55	4.50
Korea, Rep. of	1.59	2.67	3.65	3.75
Hong Kong	1.35	2.04	2.80	2.25
Singapore	2.07	3.36	4.34	4.19
Malaysia	0.93	1.75	2.30	2.10
Philippines	0.30	0.89	1.15	0.81
Thailand	0.05	0.18	0.31	0.26
Mexico	0.91	1.49	1.79	1.94
Brazil	0.21	0.30	0.44	0.45

Source: GATT, International Trade, 1985-86 (Geneva, 1986), p. 178; cited in A. Mody, Information Industries: The Changing Role of Newly Industrializing Countries (1987), p. 3.

Table 13. Technological structure of the information industry

Sector	Examples of products	Level of technology		Investment
		Design	Manufac-turing	
Advanced	Advanced semiconductors, computers, telecommunication equipment.	High	High	$100 M and above
Design Intensive	Mini/supermicro computers, s ftware, simpler telephone switching equipment.	High	Medium/Low	$5-25 M
Medium Technology	Color Televisions, video cassette recorders, disk drives, microcomputers.	Low/Medium	Low/Medium	$5-50 M
Low Technology	Black and white televisions, passive components, simpler semiconductor devices.	Low	Low	$1-20 M

Source: A. Mody, Information Industries: The Changing Role of Newly Industrializing Countries (1987), p. 13.

Table 14. Worldwide general-purpose computer market and stocks, 1977-1987[a]

	Production		Installations	
	Number	Value (million $)	Number	Value (billion $)
1977	17 800	12 500	111 500	77.7
1978	10 800	14 740	113 000	88.6
1979	10 200	15 710	105 500	98.2
1980	19 900	16 610	110 300	108.1
1981	20 200	15 120	109 400	110.3
1982	18 300	18 630	115 700	120.5
1983	16 500	21 690	118 400	131.9
1984	18 000	19 940	121 900	137.4
1985	29 400	24 600	133 600	148.1
1986	29 500	28 840	146 900	162.1
1987	28 600	27 900	159 100	172.0

Source: OECD, *Software: An Emerging Industry* (Paris, 1985), p. 21.

a/ Forecasts for the period 1984-1987.

Table 15. The top 10 independent software companies

THE TOP 10 INDEPENDENT SOFTWARE COMPANIES

Company	Primary computer market	1986 revenues Millions of dollars
LOTUS	Personal computers	$283
COMPUTER ASSOCIATES	Mainframes/minis	265
MICROSOFT	Personal computers	260
ASHTON-TATE	Personal computers	211
MANAGEMENT SCIENCE AMERICA	Mainframes	193
CULLINET SOFTWARE	Mainframes/minis	163
POLICY MANAGEMENT SYSTEMS	Mainframes	150
UCCEL	Mainframes	142
APPLIED DATA RESEARCH	Mainframes	132
SOFTWARE AG	Mainframes	130

DATA: DATAQUEST INC., BW

Source: Business Week, 11 May 1987, p. 80.

Table 16. Sales of major telecommunications equipment manufacturers, 1982 and 1983

Rank	Company/Headquarters		Sales, 1982 US$ billion	Company	Sales, 1983 US$ billion
1	AT&T/Western Electric	U.S.	12.49	AT&T Technologies*/	11.16
2	ITT	U.S.	4.87	ITT	4.86
3	Siemens	W.Germany	4.49	Siemens	4.49
4	L.M.Ericsson	Sweden	2.72	L.M.Ericsson	3.16
5	GTE	U.S.	2.72	Alcatel-Thomson(Fr)	2.74
6	Northern Telecom	Canada	2.72	Northern Telecom	2.66
7	NEC	Japan	2.17	NEC	2.41
8	GEC	U.K.	2.17	GTE (U.S.)	2.38
9	Thomson	France	1.63	Motorola (U.S.)	2.31
10	Philips	Holland	1.09	IBM (U.S.)	1.73

*/ New name following reorganisation

Sources: Arthur D. Little, cited in International Business Week, 24 October 1983 (1982 sales) and Financial Times, 12 July 1985 (1983 sales), in M. Hobday, The International Telecommunications Industry - The Impact of Microelectronics Technology and Implications for Developing Countries, UNIDO, Technology Trends Series No. 4, IPCT.31 (Vienna, 18 June 1987), p. 14.

Table 17. Worldwide semiconductor production, 1980 and 1985

	1980	1985
	(percentage)	
United States	60	47
Japan	25	39
Europe	13	11
Rest of World	2	3

Source: Financial Times, 30 June 1986, p. II.

Table 18. Japan's production and export of videotape 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: K. Hoffman, "Managing Technological Change in Developing Countries: The Impact and Policy Implications of Microelectronics", in Commonwealth Economic Papers, no. 21 (April 1986), p. 25.

Table 19. Key applications of information technology by economic sectors

Agriculture, Forestry, Fisheries

- remote sensing (to identify patterns in pest control, migration, and weather);
- farm management aids (including the use of artificial intelligence/expert systems for achieving optimum yields);
- communications systems for large farm operations/remote operations;
- advanced portable instrumentation (for moisture analysis, blood tests, etc);
- viewdata and other databases (for access to market and other data);
- simple robotics, and automatic/remote control systems (for operations such as tractor work, milking, poultry management, sheep shearing, picking and harvesting);
- marketing intelligence systems.

Primary Extractive Sector

- remote sensing (for identification of likely deposits);
- expert systems (for prospecting and extraction management);
- advanced process monitoring and control;
- IT-based management and distribution systems;
- integrated mining systems (combining extraction and finishing operations under hierarchical control);
- remote and automated extraction from hostile areas (deep sea robotics).

Construction

- computer-aided design (architecture) and prefabrication;
- IT-based management and distribution systems;
- IT-enhanced power tools, surveying equipment;
- simple robotic construction machinery.

Manufacturing

- computer-aided planning/scheduling/management;
- automated stockholding/warehousing;
- computer-aided design and draughting;
- automated handling and manipulation;
- automated manufacturing monitoring and contol;
- automated testing and quality control;
- automated packaging and despatch;
- integrated, inter-site communications (via local area networks and wide area systems).

Service Sectors

- office automation technologies, combining processing (text, voice, image), storage/retrieval and communications in both integrated and stand-alone equipment (operating within local and wide area networks);
- automated operations in fields like banking via automated telling machinery (ATM) and in retailing via electronic point of sale equipment (EPOS);
- electronic funds transfer/point of sale linkages between banks and retailers;
- expert systems/artificial intelligence-based database search and retrieval systems, providing new forms of library-type services;
- electronic mail;
- viewdata (including interactive systems);
- advanced telecommunications equipment (message forwarding, cellular radio type local/mobile communications, satellites)
- home computer-based service access (financial services, teleshopping, electronic mail/fax terminals).

Source: I. Miles and others, New IT Products and Services - Technological Potential and "Push", Report to the Long Term Perspectives Subcommittee, National Economic Development Office (Science Policy Research Unit and Innovation Research Group, Brighton, 1985), pp. 41-42.

Table 20. Market predictions for implementing production based on genetic engineering

	Number of compounds	Current market value in million dollars	Selected compound of use	Time needed to implement genetic production (years)
Amino Acids	9	1 703	Glutmate	5
			Tryptophan	5
Vitamins	6	667.7	Vitamin C	10
			Vitamin E	15
Enzymes	11	217.7	Pepsin	5
Steroid hormones	6	367.8	Cortisone	10
Peptide hormones	9	268.7	Human Growth Hormone	5
			Insulin	5
Viral antigens	9		Foot-and-Mouth Disease Virus	5
			Influenzia Viruses	10
short peptides	2	4.4	Aspartame	5
Miscellaneous proteins	2	300	Interferon	5
Antibiotics	4 a/	4 240	Penicillins	10
			Erythromycins	10
Pesticides	2 a/	100	Microbial	5
			Aromatics	10
Methane	1	12 572	Methane	10
Aliphatics (Other Than Methane)	24	2 737.5	Ethanol	5
			Ethylene Glycol	5
			Propylene Glycol	10
			Isobutylene	10
Aromatics	10	1 250.9	Aspirin	5
			Phenol	10
Inorganics	2	2 681	Hydrogen	15
			Ammonia	15
Mineral leaching	5		Uranium	
			Cobalt	
			Iron	
Biodegradation			Removal of Organic Phosphates	

Source: Alan Bull, Geoffrey Holt and Malcomb D. Lilly, Biotechnology: International Trends and Perspectives (OECD, Paris, 1982); cited in UNCTC, Transnational Corporations in Biotechnology; draft paper (UN, New York, 1987).

a/ Number indicates classes of compounds rather than number of compounds.

Table 21. New bioengineered products in agriculture and their displacement of existing products in the U.S. economy

(millions of US dollars)

Products	1983	1987	1992
New bioengineered products			
Seeds	2	20	436
Fertilizers	-	219	319
Crop protection chemicals	-	134	231
Total	2	373	986
Markets lost			
Fertilizers	-	145	360
Crop protection chemicals	-	67	231
Total	-	212	591

Source: Technology Update, 14 May 1983; cited in UNCTC, Transnational Corporations in Biotechnology; draft paper (UN, New York, 1987).

Table 22. Forecast of world markets growth in selected biotechnology products

(millions of US dollars)

	Current	1990	2000
All biotechnology products - world wide	10-60	500-27 000	65 000
All biotechnology products - Japan			16 000-24 000
Food and pharmaceutical biotechnology products	7 000		
Agricultural products (cumulative 1980-2000)			50 000-100 000
Medical products based on genetic engineering			5 000-10 000
Monoclonal antibody diagnostic products		600	
DNA probes		360	
EPO hormone		200	
Waste treatment processes-single cell protein	900	1 500	
Enzymes	500	750	
Ethanol	200	350	
Chemicals	80	250	
Microbial cultures	15	200	

Source: "Biotechnology in Wales", WINVEST, 1986, p. 5; cited in UNCTC, Transnational Corporations in Biotechnology; draft paper (UN, New York, 1987).

Table 23. Time horizons for commercialisation of genetically engineered strains

1. Currently produced		Current Market value (million dollars)
Amino acids	(arginine, asparatate, cysteine glutamate, lysine, phenylalanine, threonine, tryptophan)	1,409
Enzymes	(oc-amylase, amyloglucosidase, asparaginase, a/ Bacillus protease, glucose isomerase, glucose oxidase, papin, pepsin, rennin, tyrosine, a/ urokinase)	281
Pe[illegible] hormones	(adrenocorticotropic hormone (ACTH), bovine growth hormone, b/ endorphins, a/ enkephalins, a/ glucagon a/ human growth hormone, insulin, vasopressin a/	264
Viral antigens	(avian leukemia, avian myeloblastosis, Epstein-Barr, nepatitis, herpes, hoof and mouth, Rous sarcoma, rubella, varicella)	n.a.
Short peptides, nucleotides and miscellaneous proteins	(aspartame, glyoine-histidine-lysine interferon, human serum albumin)	304
Pesticies	(microbial)	
Aliphatios	(ethylene glycol, ethylene oxide, glycerol, itaconic acid)	1,225
Aromatics	(aspirin, ρ-acetaminophenol)	99
	TOTAL	3,544

a/ Market information not available.

b/ No market value at present.

continued

Table 23. (continued)

2. Five years		Current Market value (million dollars)
Amino acide	(methionin)	294
Vitamins	(nicotinic acid, riboflavin, vitamin B_{12} vitamin C, vitamin D)	561
Corticiods	cortisone prednisone, predisolone aldosterone)	306
Androgens	(testosterone)	11
Estrogens	(estradiol)	60
Peptide hormones	(ovine growth hormone, poroine growth hormone)	n.a
Viral antigens	(influenza)	n.a.
Short peptides, nucleotides and miscellaneous proteins	(5^{1}-IMP, 5^{1}-GMP, monoclonal antibodies)	72
Antibiotics	(penicillins, tetracyclines, cephalosporins, erythromycins)	2 560
Pesticides	(aromatics)	75
Aliphatics	(acetic acid, acrylic acid, adiplic acid, ethanolamine, isobutylene, methane, pentaerythritol, propionic acid, propylene glycol sorbiticl)	12 904
Aromatics	(aniline, benzoic acid, cresols, phenol)	663
	TOTAL	17 506

3. Ten Years	
Vitamins (vitamin E)	106
Viral antigens (reoviruses)	n.a.
Gene preparations (sickle cell anaemia)	n.a.
Aromatics (pthalic anhydride)	259
Inorganics (ammonia, hydrogen)	2 681
TOTAL	3 046

continued

Table 23. (continued)

4. Fifteen Years		Current Market Value (million dollars)
Genepreparations	(hemophilias, thallasemias)	n.a.
Aliphatics	(Bis (2-ethylhexyl) adipate), critronellal, citronellol, geraniol, linalool, linalyl acetate, nerol, a-terpineol, a-terpin acetate)	57
Aromatics	(cinnamaldehyde, diisodecyl phthalate, diocytl phthalate)	231
	TOTAL	288

4.	Current Market Value (million dollars)
1. Currently produced	3 544
2. Five years	17 506
3. Ten years	3 046
4. Fifteen years	288
TOTAL	24 384

Source: UNIDO, The Impact of Genetic Engineering on Industry, UNIDO/IS.269 (Vienna, 21 December 1981).

Note: Except for aromatics and aliphatics, all market data represent worldwide estimates. Market data for aromatics and aliphatics are restricted to the United States.

Table 24 Some recent marketing and production agreements in biotechnology

Product	Research & Development company/university	Marketing company	Type of agreement
Pharmaceutical biotechnology products	Monsanto	G.D. Searle	1985 acquisiton of G.D. Searle to help Monsanto market its biotechnology-related products
Animal health care (including interferon products)	Genentech	Ciba-Geigy	US$42 million for exclusive rights
Monoclonal antibody feline leukemia virus diagnostic kits	Cambridge BioScience Corp.	Norden Laboratories	Cambridge will supply Norden with kits for sale to veterinarians
AIDS blood screening tests	Cellular Products	Technogenics	International marketing rights
VegiSnax	DNA Plant Technology	Kraft by DNAP	Kraft will market the snacks developed
Omnivac (pseudo-rabies vaccine)	Novagene	Biologics	In return for marketing rights, Biologics will pay Novagene 50% of any profits from sales of product
Serum hepatitis *in vitro* radio-immunoassay	Centocor	Warner-Lambert and Toray-Fuji	Worldwide marketing rights. Centocor gets 20% royalties for non-exclusive marketing rights.
Animal health care products, including Genecol99 (for calf scours prevention)	Molecular Genetics	Upjohn Co.	Distribution of products to 57 international markets
Animal health care products, including Genecol99 (for calf scours prevention)	Centre for Applied Micro-Research at Porton	Porton International	13-year exclusive commercializing agent agreement
Animal health care products, including Genecol99 (for calf scours prevention)	Nova Pharmaceutical Corp.	Mitsubishi Corporation	Exclusive marketing rights for Japan
Urine test for lutinizing hormone	Hygenia Sciences	Hoffman-La Roche	Marketing agreement
Pregnancy test	Hygenia Sciences	Zer Science (Israel)	Distribution agreement
DNA probes	Amgen	Abbott Lab	US$19 million funding of kit development. Abbott will sell kits.

continued

Table 24 (cont'd)

Product	Research & Development company/university	Marketing company	Type of agreement
DNA probes	Enzo	Ortho Diagnostic Systems (Johnson & Johnson)	Exclusive worldwide marketing rights to probes in return for US$20 million investment
Erythropoietin (EPO)	Amgen	Kirin Brewery	US$24 million contract to make hormone for worldwide marketing
AIDS diagnostics	Genetic Systems Corp.	Syntex	Agreed to buy 18% of Genetic Systems in exchange for distribution rights for products developed in five years
Cattle ovulation cycle diagnostic	Boots-Celltech	Bayer AG and Sumihito and Sankyo	Bayer will manufacture and market kit worldwide except China and Japan where Sumihito and Sankyo will distribute it
Generic anticancer drugs	Ben Venue Laboratories	Cetus Corp.	50-50 joint venture for Cetus to get approval to market drugs
Immunological and biological products	Serotec Ltd. (U.K.)	Bioproducts for Science, Inc.	Exclusive U.S. distribution rights
Agricultural products	Plant Genetics	Kirin Brewery	Licensing and joint research arrangement with Kirin marketing some of Plant Genetics' products in Asia
Cardiovascular and diuretic therapeutic agents	California Biotechnology	Wyeth Laboratories (American Home Products)	Exclusive worldwide marketing license developed under a joint programme
Malaria vaccine	Biogen	Behringwerke A.G. (Heochst)	Development and marketing
Platelet-derived growth factor	Bioprocessing Ltd. (U.K.)	Bethesda Research Lab.	Distribution in the U.S.A. and Canada
Monoclonal antibody kits to detect turfgrass diseases	Agri-Diagnostics	O.M. Scott & Sons	Marketing of kits developed by DNAP and Koppers' joint venture
Human growth hormone	Biotechnology General Corp.	ABI Biotechnology (Canada)	Exclusive rights to distribute product
Monoclonal antibodies	Ube Industries Ltd. (Japan)	Wako Pure Chemical Industries Ltd. (Japan)	Marketing agreement
Diagnostics	Liposome Technology Inc.	Cooper Laboratories	Joint marketing venture (Cooper-Lipotech)

continued

Table 24(cont'd)

Product	Research & Development company/university	Marketing company	Type of agreement
Liposome-based assay kits	Collaborative Research	Sterling Drugs	Marketing to over-the-counter markets
Monoclonal antibody treatment of mastitis in cows	Molecular Genetics	Eastman Kodak	Development and marketing
Human granulocyte colony stimulating factor	Amgen	Memorial Sloan-Kettering	Production and distribution
Hepatitis B test	Organon Teknika Corp.	Electro-Nucleonics	Marketing in the U.S.A. and Canada
Alpha interferon	Biogen	Schering-Plough	Licensing agreement--Schering-Plough has a 10.8% share of Biogen. Manufacturing of the drug is in Biogen's US$54 millio· plant in Ireland.
Chemotherapeutic drugs	Cetus Corp./Ben Venue Laboratories	Cetus-Ben Venue Therapeutics	Joint venture to market anti-cancer products. Methotrexate is its first product.
Salinomycin antibiotic	Kaken Pharmaceutical Co.	Kaken in China, Robins in the U.S., Hoechst in Europe and Pfizer in Canada and South America	Worldwide marketing of Kaken's product
Snomax	Advanced Genetic Sciences	Eastman Kodak	Production of AGS's ice formation product.
Snomax	Advanced Genetic Sciences	Karlshamns Oljefabriker A.B.	Marketing of Snomax in Sweden and expansion into Europe.
Lung surfactant	California Biotechnology	Byk Gulden Lomberg Chemische Fabrik GmbH	European marketing rights
Growth factors	Chiron	Johnson & Johnson	Distribution and marketing
Semposai	Kirin Brewery	Tokita Seed	Marketing of new vegetable hybrid.
Hepatitis B vaccine	Chiron Corp.	Merck Sharp & Dohme	Marketing of gene-splicing vaccine
Human tumor necrosis factor-producing bacterium	Biogen	Suntory Ltd.	Suntory will produce and sell products in Japan and South East Asia

continued

Sources: "New Commercial Opportunities for Liposomes Emerge", Bio/Technology, April 1985; "Biotech Breakthroughs in Detecting Disease", Fortune, 9 July 1984; "Interferon Lifts Schering-Plough Hopes", New York Times, 13 January 1986; "Syntex to Acquire 18% of Genetics", New York Times, 20 August 1985; "Japan Roundup", Bio/Technology, January and September 1985 and April, July and November 1986; DNA Plant Technology 1985 10-K Report; "Biologics' Historic Product", New York Times, 27 May 1986; "Small U.S. Biotech Firm Testing Products with Commercial Potential", Chemical & Engineering News, 25 March 1985; "Growing Pains Give Biotechnology Firms Mixed Results in Quarter", Chemical & Engineering News, 10 June 1985; "Cetus-Ben Venue: A Deal with a Twist", Bio/Technology, November 1985; "Chronicle", Biotechnology, May, September, November and December 1985 and January, March, April, August and November 1986; "Biotechnology Deal at Eastman Kodak", New York Times, 7 October 1986; "A Shot in the Arm for Vaccine Makers", Business Week, 4 August 1986.

Cited in D. Dembo and W. Morehouse, Trends in Biotechnology Development and Transfer, UNIDO, Technology Trends Series No. 6, IPCT.32 (Vienna, 19 June 1987), pp. 46-49.

Figure IV. The segmented electronics industry of the 1970s

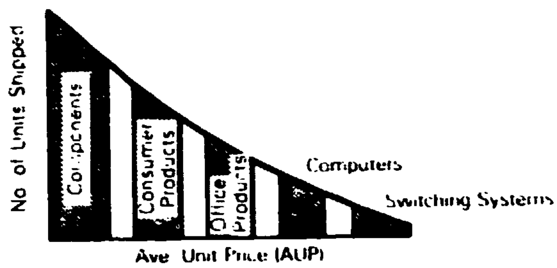


Figure V. The desegregated electronics industry of the 1980s

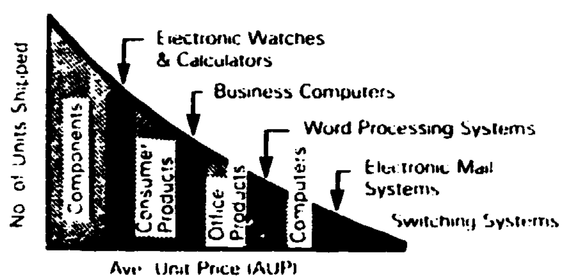
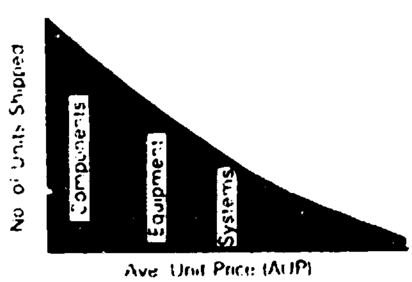
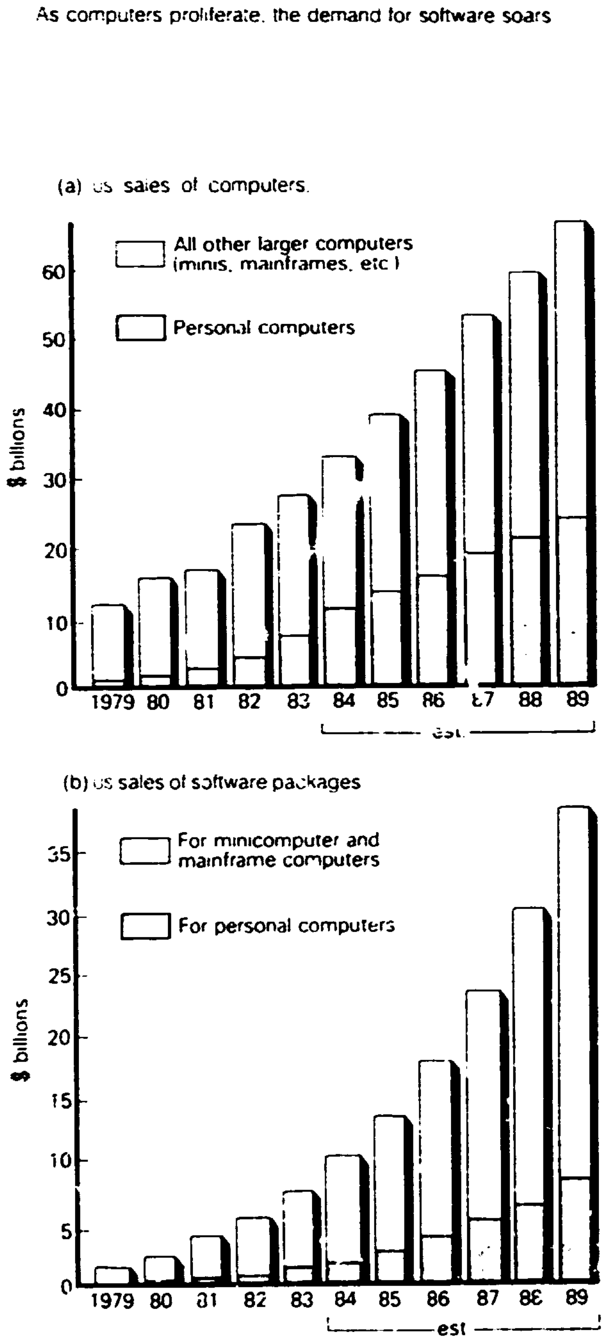


Figure VI. The product continuum of the 1990s



Source: I. Mackintosh, Sunrise Europe, The Dynamics of Information Technology (Oxford, Basil Blackwell, 1986), pp. 107-108.

Figure VII. U.S. Sales of computers and software packages



Source: Business Week, 27 February 1984, reproduced in The Information Technology Revolution, T. Forester, ed. (Oxford, Basil Blackwell, 1985), p. 28.

Figure VIII. Main-line merchant IC producers (worldwide)

1972	1977	1982
AMD	AMD	AMD
AMI	AMI	Intel
AMS	Electronic Arrays	National Semi
Electronic Arrays	Fairchild	SGS-ATES
Fairchild	Intel	
Intel	Intersil	
Intersil	MMI	
MMI	Mostek	
Mostek	National Semi	
National Semi	SGS-ATES	
PMI	Siliconix	
SGS-ATES	Synertek	
Siliconix	Zilog	

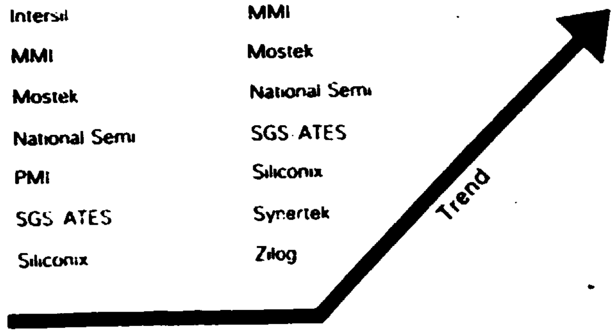
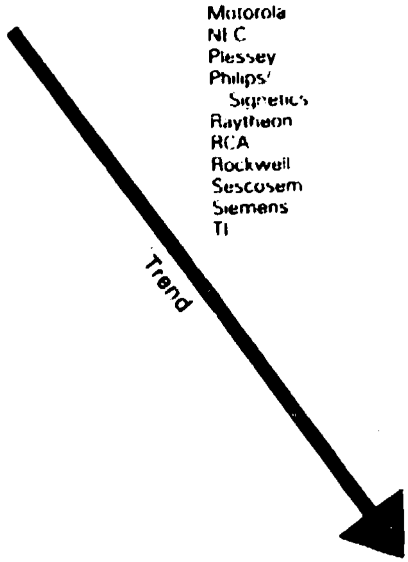


Figure IX. Vertically integrated/merchant IC vendors (worldwide)

1970	1976	1985
ITT	AEG Telefunken	Bourns/PMI
Motorola	Ferranti	Exxon/Zilog
Raytheon	GI	Ferranti
RCA	Harris	Fujitsu
TI	Hughes	GE/Intersil
	ITT	GI
	Motorola	Gould/AMI
	NEC	Harris
	Plessey	Hitachi
	Philips/Signetics	Hughes
	Raytheon	ITT
	RCA	Matsushita
	Rockwell	Mitsubishi
	Sescosem	Motorola
	Siemens	NEC
	TI	OKI
		Philips/Signetics
		Plessey
		Raytheon
		RCA
		Rockwell
		Schlumberger/Fairchild
		Sharp
		Siemens
		Sprague
		Thomson-CSF
		Thorn-EMI-Inmos
		TI
		Toshiba
		TRW
		UTC/Mostek



Source: I. Mackintosh, Sunrise Europe, The Dynamics of Information Technology (Oxford, Basil Blackwell, 1986), pp. 120-121.

Figure X. The new shape of the merchant IC industry

Standard IC makers

Advanced Micro Devices
Cherry Semiconductor
Intel
Eurosil electronic
Exar
Fairchild Semiconductor
General Instrument
Inmos
International Rectifier
Matra-Harris
Micron Technology
Monolithic Memories
Motorola Semiconductor Products Sector
National Semiconductor
SGS Microelettronica
Siliconix
Sprague
Standard Microsystems
Texas Instruments
Western Digital
Zilog

Vertically integrated companies

AT&T
Ford Microelectronics
GE/RCA/Intersil
GM/Hughes Electronics
Gould
GTE Microcircuits
Harris
Honeywell
ITT Semiconductor
Mitel
NCR
Philips/Signetics
Plessey
Raytheon
Rockwell International
Siemens
Telefunken electronic
Thompson Components-Mostek
TRW
All major Japanese and Korean semiconductor producers

Design houses

Digital	*Linear*
Altera	Anadigics
Brooktree	Analog Devices
Dallas Semiconductor	Burr-Brown
Lattice Semiconductor	Crystal Semiconductor
Chips & Technologies	Linear Technology
Cirrus Logic	Maxim
Faraday	Micro Linear
Integrated Device Technology	Precision Monolithics
Logic Devices	Silicon Systems
MOS Electronics	
Vitelic	
Weitek	
Xilinx	
Zoran	

Process specialists

Bipolar Integrated Technology
Catalyst Semiconductor
Cypress Semiconductor
Exel Microelectronics
Gazelle Microcircuits
GigaBit Logic
Hypres
Inova Microelectronics
International Microelectronic Products
Micro Power Systems
Mosaic Systems
Orbit Semiconductor
Performance Semiconductor
Seeq Technology
Sierra Semiconductor
TriQuint
Vitesse Electronics
Xicor

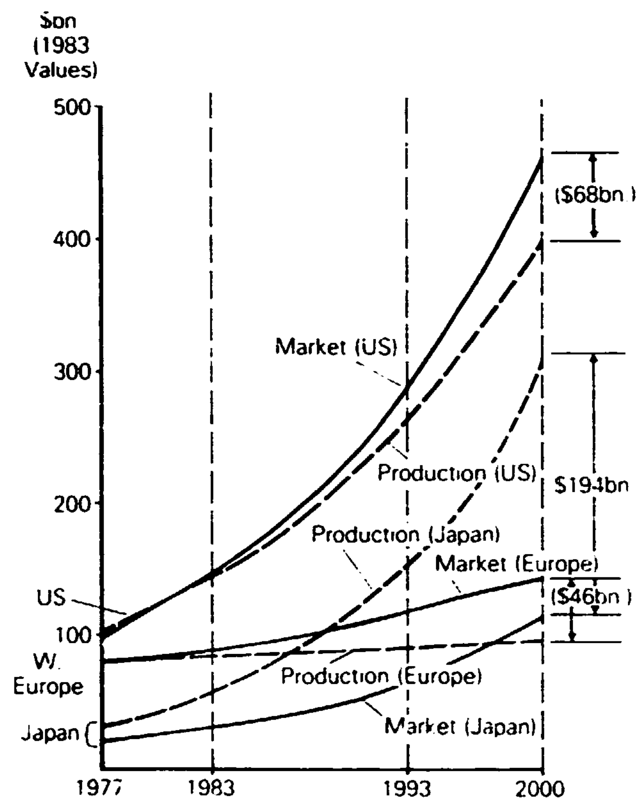
Semicustom houses

Actel
Applied Microcircuits
California Devices
Ferranti
Integrated Logic Systems
International Microcircuits
LSI Logic
Micam Associates
Micro Linear
Solid State Scientific
VLSI Technology
Waferscale
Zymos

NOTE: In the representative listing, a number of companies fit in more than one category. They are placed under the heading of their most important business.

Source: Electronics, 2 April 1987.

Figure XI. Projected electronics production and markets in Western Europe, Japan and the United States



Source: I. Mackintosh, Sunrise Europe, The Dynamics of Information Technology (Oxford, Basil Blackwell, 1986), p. 97.

III. DEVELOPMENT AND USE OF MATERIALS

The development and use of materials have such a wide-ranging impact that they need to be treated and understood as an "across-the-board" technological development comprising a collection of new manufacturing technologies or new product technologies applied to existing or new materials. The need to conserve energy and resources has led to product and process changes resulting in a reduction in consumption density (ratio of industrial raw material consumption to GNP) for major metals such as iron, copper, zinc and lead and to a lesser extent for lightweight raw materials like aluminium. Another important general trend is the broad movement towards materials with a greater knowledge content per unit weight. Future developments in the field of materials are expected to involve a greater degree of information content or a greater degree of intellectual sophistication for each unit of material. Advanced materials, it is argued, are not mere substitutes for existing materials but creative agents for the new age of industry.

Figure XII plots the amount of materials per unit of product against the amount of sophistication attached to the use of a given material.

The gravity center of several major materials-producing industries has been indicated in this heuristic model together with a vector, shown as an arrow, to indicate what the trend in the next decade will be. Older industries like steel and cement have limited possibilities of moving the gravity center of their product mix considerably within the next decade or so towards more sophisticated uses or drastically new technologies. For instance the basic steel industry will move only slowly out of its present position because the bulk of steel is used for rather simple products like railroad tracks or simple beams for construction. Highly specialized steels like high-strength, low-alloy steel (HSLA), shown separately, have a brighter future.

High-temperature materials already have a lot of built-in sophistication as well as know-how in their final use. The opportunities for the high-temperature resistant materials and younger and lightweight materials like plastics, aluminium, titanium and magnesium are more dynamic. It can be easily recognized that the automobile industry will move, like most other materials-using industries, to the upper left of the heuristic model. For all vectors indicating innovative moves, R&D and new technologies will have a considerable impact within the next decade or so. An example would be the microprocessor industry, which would be placed around electronic materials on the upper left of the heuristic model. (Altenpohl, 1980, pp. 200-201)

According to a study, "The Present Condition and Perspective of New Materials", prepared for Japan's MITI, the market scale for new materials alone is some Y5.4 trillion (in 1981 values); the market scale for existing materials that can be put to use for new products to appear with the advent of new materials is some Y4.8 trillion; the market scale for intermediary products consumed in the process of manufacturing these new products - say, production-inducement effect - is some Y11.2 trillion; the market scale for products employing new materials is some Y41.6 trillion; and the total scale is estimated to reach some Y63 trillion. As for the impact on industrial structure, the study predicts that not only will enterprises tackling the study of new materials be presented with business opportunities to expand, but new materials will also form a new industrial area. (Nikko Material, June 1984, pp. 14-18)

In the same study the fine ceramics and new metal material markets (both of which centre mainly on large-scale IC materials such as semiconductor monocrystal and plates) are estimated at Y1.9 trillion and Y1.5 trillion, respectively; the markets for high-functioning, high-polymer materials and composite materials (both of which centre on lightweight structure materials) are estimated at Y1.5 trillion and Y0.4 trillion, respectively.

By functional classification, the scale of the market for electrical function materials such as those for large-scale IC circuits is estimated at Y2.5 trillion; for the lightweight structure material as core mechanical function materials market, at Y1.9 trillion; for optical function materials market with optical fibers, at Y0.6 trillion; followed by the thermal function metals market, which has heat-proof structural materials at its core, at Y0.6 trillion.

The following materials and technologies are among the major developments in the field that are likely to make a considerable impact on society up to the turn of the century: (Czichos, 1985, p. 3)

. Synthetic polymers
. High-performance resin- and metal-matrix composites
. Surface technologies (e.g. laser treatments)
. Silicon nitride and silicon carbide ceramics
. High strength low alloy steels
. Rapidly-solidified superalloys
. Single-crystal machinery components (e.g. turbine blades)
. Fibre optic transmissions
. VLSI silicon chips
. Improved high-capacity computer memories ("magnetic bubble memories")
. Semiconductor integrated detectors
. Powder metallurgy techniques
. Precision-casting technologies ("net shape fabrication")
. Computer-aided design and manufacturing (CAD, CAM)

Some of the latest achievements in the field of advanced materials and related research and technology are described below. (Czichos, 1985, pp. 19-29)

A. Metals and alloys

For basic metals such as iron, steel, aluminium and copper, incremental improvements in specific properties are expected rather than striking advances on a broad front. Newer metals whose uses have grown during the past three decades include the reactive metals - titanium, zirconium, and hafnium - and the refractory metals - niobium, tantalum, molybdenum, and tungsten. Titanium, which has some favourable properties like high strength, low specific weight and excellent corrosion resistance, is of particular importance in aircraft constructions. It will also be used in other applications: chemical plants, heat exchangers, electrodes, marine technology, power plants (nuclear, coal-fired and geothermal). Further examples of new developments in metals and alloys in recent years are:

1. Superalloys

Alloys based on nickel, cobalt or iron and intended for service above 500°C are frequently termed superalloys. They are used for turbines and compressor discs, turbine vanes and blades, and other hot components. The use of high-temperature nickel and cobalt alloys for turbine blades, with special anisotropic grain structures obtained by controlled solidification, will make it possible to increase the operating temperature of gas turbines beyond 950°C, thereby increasing the thrust:weight ratio by 15 per cent. The use of directionally solidified materials and single-crystal components will increase the durability of equipment such as turbines and may increase peak operating temperatures and thus efficiency.

2. High-strength, low-alloy steels (HSLA steels)

HSLA steels comprise a relatively new class of engineering materials. They are low-carbon steels, modified with a small addition of one of the following elements: vanadium, neobium or titanium. Since the addition of one (or a combination) of these three elements is usually less than 0.1 per cent, the term microalloying is frequently applied to this class of steels. Compared to common carbon steels, HSLA steels exhibit a yield strength two to three times higher. In addition to strength, the new steels exhibit an attractive balance of engineering properties such as ductility, toughness and weldability. Low-carbon microalloyed HSLA steels are being produced as bars, sheets, plates, structural shapes and tubular products. In addition, in medium and high carbon steel grades, small amounts of vanadium have been found useful in the production of cold drawn bars forging steels and rail steels, leading to great reduction in the general steel construction, fabrication and ship-building industries.

3. Glassy metals

These materials consist of metals like iron, cobalt and nickel alloyed with elements such as phosphorus, silicon and boron, and are solidified in noncrystalline or amorphous form such as glass by very fast cooling. Advantages of these materials: considerably improved magnetic and electrical properties compared with crystalline metals, higher mechanical strength and corrosion resistance. They can be used to advantage in the following applications: cores for electrical windings and transformers, television and magnetic tape technology. The replacement of conventional transformer cores has been estimated to result in potential savings of electrical energy losses in the United States equivalent to 6 million barrels, i.e. approximately 10^9 liters of oil per year.

B. Inorganic materials; ceramics

Ceramics may be broadly defined as inorganic non-metallic materials processed or consolidated at high temperatures. Several new classes of "high-performance" ceramics (base: high-purity oxides such as aluminium oxide and synthetic carbides, nitrides, borides, silicates and phosphates) with special advanced properties are currently being investigated at materials research laboratories. The technical advantages of ceramics are: readily available raw materials, high chemical and thermal stability, and extremely high hardness values. The range of industrial applications cover: electrical insulation components, cutting and forming tools, bearing materials, nozzles and chemical pumps through biotechnical materials such as artificial hip joints and housings for microelectronics chips. Non-oxidizing thermally stable materials such as silicon nitride are suitable in principle for use both in diesel engines and gas turbines and in high-performance cutting tools. Table 25 provides a systematic classification of high-performance ceramics by functions.

By 1990 the value of ceramics used by the automotive industry in Japan is estimated to reach $1.5 billion for cars and $1.4 billion for other vehicles. If the present intensive research efforts on engines based on ceramics are successful, the figures may be even higher.

C. Organic materials; polymers

A broad variety of useful plastics, elastomers and other polymers have become commercial products in recent years. They are at present the fastest-growing class of materials. Trends in polymers are at the forefront of future technologies. Commercial developments over the past two decades include:

(a) polyamide fibres with strength and modulus properties superior to many materials commercially available today;

(b) temperature-resistant aromatic polymers which will displace many strategic metals for elevated temperature applications;

(c) electronically active polymers with electrical conductivities close to those of conventional metals;

(d) improved thermoplastic resins suitable for stamping out high production rate, fibre-reinforced composite parts; and,

(e) polymer blends, alloys and multicomponent structures with optimum combinations of properties.

There is a continuing interest in developing high-performance polymer materials that are light in weight but as strong as metal. Development of these materials is considered possible through the technique of high crystallization. They are expected to replace structural materials made of aluminium or steel. Thus, the areas of construction (e.g., thermal insulation, seeding) packaging and containers will remain major markets for plastics in the years ahead. In addition, the automobile industry is a growing market for plastics, in part as weight-saving replacements for steel. For example, bumper systems employing reaction-injection molded urethane fascias are already familiar and new bumper systems employing injection-molded blends of polycarbonate and polyester to form a "toughened" polymer alloy are currently being introduced in the United States and Europe. These new bumper systems will offer an eight-pound weight savings over an unadorned high-strength steel bumper. Other applications of advanced polymers to automobiles will include the tires, structural components, panelling, upholstery, trim, battery, electrical distribution system, and electrical sensors and displays.

D. Composite materials

Composite materials are made up of two or more component materials, each individual and separate but intimately interconnected. Composite materials generally fall into the following main categories:

(a) fibre-reinforced materials;

(b) surface-coated materials;

(c) layered materials; and,

(d) particle-composite materials.

The materials for the matrix and the constituents (fibres, coatings, layers, particles) may consist of any of the main types of materials (metals, ceramics, plastics, cement, glass, rubber).

Composite materials are always used in the pursuit of a specific technological aim: to improve performance compared with the use of single-component materials in terms of resistance to corrosion or wear, appearance of optical characteristics, thermo-mechanical strength, heat or noise insulation, or weight reduction for energy-saving purposes. The quest for new materials with higher strength and stiffness relative to their density for transportation systems has led to increasing use of composite materials consisting of reinforcing fibres of carbon polymers, metals and ceramics embedded in matrices of polymer resins, metals and ceramics. Larger percentages of the structural weight of airframes for aircrafts are now being fabricated from graphite-plastics. Furthermore, these composites are finding increasing use for helicopter rotors and propellers. Applications of composite materials in cars, trucks and off-highway equipment are also increasing considerably and will continue to expand as processes yield products with more reproducible properties and as designers devise more effective joining methods.

E. Information-related materials

Materials play a crucial role in contemporary and future information technology as illustrated briefly in the following examples.

1. Transistor and computer materials

Electronics are possibly the most rapidly accelerating area in technology today, with silicon remaining the most emphasized electronic material in the near term. Due to the ability to control the composition, structure and processing of silicon-based components, the number of electronic components on a single integrated circuit silicon chip has doubled and the cost per component has fallen by nearly half annually for about two decades. A strong effort is under way in the development of new lithographic techniques employing electron beams and X-rays and of dry processing techniques such as plasma-etching and laser-annealed ion implantation. In addition a technology is being developed rapidly for producing computer memory using magnetic substances such as gadolinium-iron-garnet ("bubble-memories"). These bubble-memories store information at very high density as microscopic magneticized domains.

2. Fibre optics

Glass and quartz fibres have been developed through which information in the form of light signals can be transmitted over several miles. At present optical communication systems are built around discrete optical components. The source is driven by electronics and the optical signal goes directly from the fibre into a detector which converts it back into an electronic signal. Communication by fibre optic transmission is well advanced and will see major growth in the next years.

3. Electronic displays

Electronic displays will continue to replace most of the mechanical devises now used to depict letters and numbers in cash registers, home appliances, instrument panels and other equipment. Such displays will use light-emitting diodes, liquid crystals and gas-discharge devices and will be driven by digital circuitry. R&D efforts focus on the performance of the materials currently limiting the utility of these devices.

F. Materials processing and manufacturing

Materials processing is, broadly speaking, the conversion of raw materials into intermediate or finished products with useful shapes and properties. In the past 50 years productivity and product quality in basic materials industries like the metals industries have been vastly improved by important engineering advances in materials processes and manufacturing. Examples are: continuous rolling of strip, automatic gauge (thickness), control, electronic inspection of tubes and computer control of rolling mills. Further advances resulted from the development of the numerically controlled machine tool in the 1950s and the evolution of computer-aided manufacturing (CAM) techniques. In full-scale use, CAM will be capable of providing computer generation of the optimized production plans including selection of processes, equipment, tooling and operating conditions. This further leads to optimised production control, namely the dynamic scheduling of the work, maximising and balancing the use of the manufacturing equipment and minimising the time that parts lie waiting to be worked on. Finally, CAM helps to realise the automated machining of the parts by numerical control of machine tools. Numerical control and design data are combined with manufacturing data to produce a control programme. The progamme is then used via punched tape or small computer to control one or more machine tools that produce the finished parts from raw stock.

In addition, the last decades have provided many notable advances in near-net shape fabrication methods, greatly reducing or in some cases eliminating the need for final machining or grinding operations. For example, in sophisticated production techniques, turbine blades are now being produced by single-crystal castings and complex shapes are being commercially produced by one-step superplastic forging of powdered-metal billets. Advances in cutting tool materials are fulfilling needs for higher tool speeds and material removal rates. The availability of advanced ceramics, ceramic-metallic compacts, intermetallic compounds and ceramic coatings has been a key asset in contemporary manufacturing and materials processing technologies.

Further advances in materials processes include:

- laser and electron-beam surface heat treatment
- plasma processing
- photon-activated chemical reactions
- dynamic compaction of ceramic and metal powders
- microjoining
- diffusion bonding
- molecular-beam epetaxy
- rapid solidification
- high pressure synthesis
- hot-isostatic pressing
- convection-free crystal growth
- microencapsulation

G. Industrial and technology market structure

Full information on the emerging industrial and technology market structure is not available for all materials. But to illustrate, the trends in ceramics and fibre optics are discussed.

In 1986, world sales of engineering ceramics were $6 billion; by the early 1990s they are expected to be approximately $18 billion. Further research is needed because ceramics are still brittle; in addition, new applications are constantly being sought. Table 26 illustrates the wide disparities in R&D spending in this one area of new materials.

Firms moving into new ceramics tend to fall under one of three groups. First are materials manufacturers that are diversifying into new materials because of perceived opportunities to develop their existing technology in ways that will enable them to achieve higher levels of value added. This tends to be the motivation of firms entering from the textile, petrochemical and metal industries. Porcelain and glass industries usually make up the second group. These industries are seizing the opportunity to upgrade their existing technology through the results of accumulated R&D on the properties of the products they have long been producing. The third group, consisting of firms in processing and assembly industries, has identified its own need for new materials. Firms in the electrical equipment and automobile manufacturing industries, for example, have identified uses for new ceramics.

In electro-ceramics and in the development of sensors, many smaller and venture companies are emerging as strong contenders. But in engineering ceramics, large companies have an advantage. Automobile manufacturers that enter into joint agreements with ceramics makers have an edge since they already control the market for engines. They are unlikely to contract out work for engine development since the engine is such an essential part of their final product. (Kimura, 1983; cited in UNIDO, Advances in Materials Technology: Monitor, 2, August 1984, pp. 16-17)

In fibre optics, the United States accounts for over 50 per cent of the world market. An interesting picture emerges from an assessment of the U.S. fibre optics industry: the main products (cable, connectors and receivers/transmitters) are all highly concentrated and interconnected via vertically integrated producers. Both in 1983 and 1984, more than 90 per cent of cable fibre shipments were supplied by just five companies. Western Electric alone had a market share of 50 per cent. Ever since the divestiture of the AT&T system, the role of Western Electric has changed somewhat. In the past, nearly all of its output was sold to the Bell system. But now Western Electric can engage in markets outside the Bell system, extending to international markets, via AT&T International. Since it is a very large, low-cost producer, Western Electric represents a real threat to all the other suppliers.

Table 27 indicates the extent of vertical integration within the world fibre/cable supply industry. Majority of the firms are vertically integrated. Out of 93 suppliers, only 18 sell either fibre or cable alone. The rest of the firms deal with one or more segments of the market.

Apart from the United States and Canada (in the form of Northern Telecom), at least seven countries - France, the FRG, Italy, Japan, the Netherlands, Sweden and the United Kingdom - have considerable production capacity in fibre optics. In Japan, the industry is part of the Optoelectronic Industry and Technology Development Association, which includes representatives from electronics, telecommunications and glass firms. Japanese firms, though largely supplying the domestic market, have become more active recently in developing countries such as Argentina, India and Singapore.

Other countries also have a central body that co-ordinates national efforts in fibre optics. In France, it is the "Centre National d'Etudes des Télécommunications". In the FRG, the "Kabelkartell" - which has been attempting to direct the German fibre optics industry comprising Siemens, Standard Elektrek Lorenz, Philips, AEG and Kabelmetall - has been successfully challenged by Wacker Chemie, a large supplier of chemicals to the semiconductor industry.

The market for fibre optic transmitters is dominated by the suppliers of complete telecommunications systems. The connector market, on the other hand, is dominated by 25 firms specialising in connector production but are otherwise not engaged in the fibre optics market.

The reason for the industry's relatively high level of vertical integration stems from the fact that some national telecommunication administrations demand readily usable, whole systems. It then becomes the supplier's responsibility to ensure that the system is workable and properly integrated. This practice is also in the interests of suppliers since they receive large orders.

However, a large number of market niches are available to specialised producers, especially for local area networks (LANs) and the very short-distance segment of the market. This does provide a point of entry for new suppliers.

An interesting pattern now emerging is that in every country using fibre optics on a large scale in its telecommunications industry, strong ties exist between the demand and supply sides of the market. The major users of fibre optic systems and components usually enter into contracts with a limited number of suppliers. Suppliers are either often affiliated with the users, as in the case of AT&T and Western Electric, or they co-operate through official, institutionalised channels, as in the FRG, France and Japan. In practice, market entrance is severely restricted in several countries; only in the short distance markets are there possibilities for new entrants. (Bonek, Furch and Otruba, 1985, pp. 209-213)

Table 25. Classification of high-technology ceramics by function

Function	Material	Product / element	Application
Electric functions	Insulation materials (Al_2O_3, BeO, MgO)	IC circuit substrate, package, wiring substrate, resistor substrate, electronics interconnection substrate	
	Ferroelectrics materials ($BaTiO_3$, $SrTiO_3$)	Ceramic capacitor	
	Piezoelectric materials (PZT)	Vibrator, oscillator, filter, etc.	
		Transducer, ultrasonic humidifier, piezoelectric spark generator, etc.	
	Semiconductor materials ($BaTiO_3$, SiC, ZnO-Bi_2O_3, V_2O_5 and other transition metal oxides)	NTC thermistor:	temperature sensor, temperature compensation, etc.
		PTC thermistor:	heater element, switch, temperature compensation, etc.
		CTR thermistor:	heat sensor element
		Thick film thermistor:	infrared sensor
		Varistor:	noise elimination, surge current absorber, lighting arrestor, etc.
		Sintered CdS material:	solar cell
		SiC heater:	electric furnace heater, miniature heater, etc.
	Ion conducting materials (β-Al_2O_3, ZrO_2)	Solid electrolyte for sodium battery	
		ZrO_2 ceramics:	oxygen sensor, pH meter fuel cells
Magnetic functions	Soft ferrite	Magnetic recording head, temperature sensor, etc.	
	Hard ferrite	Ferrite magnet, fractional horse power motors, etc.	
Optical functions	Translucent alumina	High pressure sodium vapor lamp	
	Translucent magnesium, mullite, etc.	For a lighting tube, special purpose lamp, infrared transmission window materials	
	Translucent Y_2O_3-ThO_2 ceramics	Laser material	
	PLZT ceramics	Light memory element, video display & storage system, light modulation element, light shutter, light valve	
Chemical functions	Gas sensor (ZnO, Fe_2O_3, SnO_2)	Gas leakage alarm, automatic ventilation fan, hydrocarbon, fluorocarbon detectors, etc.	
	Humidity sensor ($MgCr_2O_4$-TiO_2)	Cooking control element in microwave oven, etc.	
	Catalyst carrier (cordierite)	Catalyst carrier for emission control	
	Organic catalyst	Enzyme carrier, zeolites	
	Electrodes (titanates, sulfides, borides)	Electrowinning aluminum, photochemical processes, chlorine production	
Thermal functions (ZrO_2, TiO_2 ceramics)		Infrared radiator	
Mechanical functions	Cutting tools (Al_2O_3, TiC, TiN, others)	Ceramic tool, sintered SBN	
		Cermet tool, artificial diamond	
		Nitride tool	
	Wear resistant materials (Al_2O_3, ZrO_2)	Mechanical seal, ceramic liner, bearings, thread guide, pressure sensors	
	Heat resistant materials (SiC, Al_2O_3, Si_3N_4, others)	Ceramic engine, turbine blade, heat exchangers, welding burner nozzle, high frequency combustion crucibles	
Biological functions	Alumina ceramics implantation	Artificial tooth root, bone, and joint	
	Hydroxyapatite bioglass	Artificial tooth root, bone, and joint	
Nuclear functions	Nuclear fuels (UO_2, UO_2-PuO_2)		
	Cladding material (C, SiC, B_4C)		
	Shielding material (SiC, Al_2O_3, C, B_4C)		

Source: H. Czichos, Materials Technologies and Techno-Economic Development, Forschungsbericht 117 (German Foundation for International Development, Berlin, October 1985), p. 41.

Table 26. R&D spending on engineering ceramics, 1985

Country	(millions of U.S. dollars)
Japan	300.0
United States	100.0
Federal Republic of Germany	5.0
Sweden	0.5
United Kingdom	3.0
France	5.0

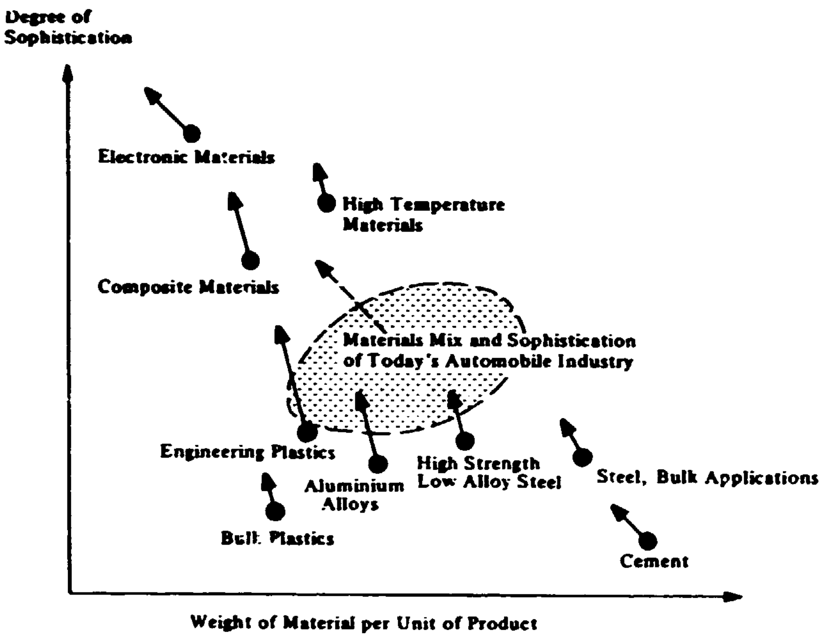
Source: IAL, cited in *Financial Times*, 30 June 1986, p. VI.

Table 27: Vertical integration among fibre/cable suppliers

Product	Number of suppliers
fibre only	6
cable only	12
fibre & cable	20
fibre & other components	3
cable & other components	8
fibre, cable & other components	14
unclear production programme	30
Total	93

Source: E. Bonek, B. Furch, H. Otruba, Optical Fiber Production, UNIDO/IS. 542 (Vienna, 1985), p. 211.

Figure XII. Heuristic model providing correlation between quantity of material in a given product and "information" attached to material and its use



Source: D. Altenpohl, Materials in World Perspective (Springer-Verlag Berlin, Heidelberg, N.Y., 1980), p. 201.

Note: Each point indicates schematically the gravity center of a given material (or group of materials) in the mid-70s. The vectors show trends for the next decade or so. "Degree of Sophistication" is know-how ("software") built into either the material and/or the final product.

IV. CHANGING CONCEPTS OF INDUSTRIAL ORGANISATION AND PRODUCTION

Recent trends in automation essentially involve the employment of factory-wide systems, with information technology as the operational link. Such trends could be subsumed under the rubric of "advances in manufacturing technology", which bid fair to create "the factory of the future". The changes in the concept of industrial organisation and production are no less, if not more, fundamental than any specific new technology. The following discussion is centred on flexible manufacturing systems and robotics.

The total world market for industrial automation equipment (1) in 1983 was estimated at $15 billion. By 1989 the market is expected to more than quadruple. Table 28 presents estimated investments in shop-floor automation in the United States.

A. Flexible manufacturing systems (FMS)

So far, no internationally agreed definition of exactly what constitutes a flexible manufacturing system exists. However, definitions are beginning to merge as experience in designing and using FMS grows. The United Nations and the Economic Commission for Europe have adopted this description:

> A flexible manufacturing system (FMS) is an integrated computer-controlled complex of numerically controlled machine tools, automated material and tool-handling devices, and automated measuring and testing equipment that, with a minimum of manual intervention and short change-over time, can process any product belonging to certain specified families of products within its stated capability and to a predetermined schedule. (UN/ECE, 1986, p. 13)

A number of related concepts also need clarification:

Direct numerical control is a system connecting numerically controlled machine tools to a common memory, which has the capacity to provide data to the machines. Direct numerical control was originally used to describe . system in which two or more numerically controlled machines were controlled by a common computer system. The term is now used to describe a system in which programmes are stored centrally and located onto individual machines as required.

Robots come in many shapes, sizes and abilities. Described simply, a robot is a reprogrammable device designed to manipulate and to transport parts or tools through variable programmed motions. Robots vary in arm geometry, drive systems, dynamic performance and accuracy, and reliability. (UN/ECE, 1985, pp. 13-15)

A computer-aided design system (CAD) incorporates one or more computers when carrying out some of the calculations and actions involved in the design process.

A computer-aided manufacturing system (CAM) incorporates one or more computers when undertaking some of the tasks involved in the organisation, scheduling and control of manufacturing process operations.

A computer-integrated manufacturing system (CIM) consists of software and hardware, which together are involved in product design, production planning, production control, production equipment and production processes. Two or more manufacturing operations are controlled by the same computer. More research in systems engineering would enable computer-integrated manufacturing sytems to realize their full potential. (UN/ECE, 1986, pp. 18-20) Figure XIII describes how functions and production processes can be integrated under a CIM.

As its name implies, flexibility is the most important characteristic of a flexible manufacturing system. Machine flexibility refers to the ease with which the machines can be reset according to tooling or positioning. Process flexibility refers to the ability to produce in a number of different ways a given set of parts, each possibly using different materials. Most important is product flexibility, the ability to change over to produce a different set of products quickly and economically. Then there is flexibility in routing, volume, expansion, operation and production. (UN/ECE, 1986, pp. 20-22)

Since there is no universally agreed definition of what flexible manufacturing systems encompass, the extent of their use is difficult to determine. Despite the varying definitions, Figure XIV (2) provides some idea of the order of magnitude of the diffusion of FMS in industrialised countries. For example, in Japan, flexible manufacturing systems have increased from five in 1975 to more than 100 today; the USSR installed its first flexible manufacturing system in 1968 and by 1985 it had 60.

A flexible manufacturing system is made up of many different mechanical, electronic and software components and subsystems. Few companies have the capability to manufacture all the necessary parts for a complete, operational FMS. Therefore, a joint venture of component manufacturers often supplies the FMS. One of the component manufacturers acts as the main contractor, usually the company responsible for the largest share of the total system. For different sorts of flexible manufacturing systems, the main contractors are:

Flexible manufacturing system	Main contractors
metal-cutting	suppliers of machining centres, turning centres or head indexers
metal-forming	suppliers of metal-forming machines
welding and assembly	suppliers of industrial robots

Suppliers of material-handling equipment and systems engineering firms also act as main contractors in some cases. Firms that produce control systems and computer and communications equipment rarely act as main contractors.

These joint ventures are usually arranged ad hoc for a particular FMS installation. The absence of permanent arrangements between FMS component suppliers gives the user more freedom to pick and choose. Of course this is valuable only if users know what they want and need. On the other hand, joint ventures can lead to higher prices as each component manufacturer has to be able to provide the necessary interface for many different sorts of machines.

Often the user acts as the main contractor. More likely this would be the case in a large company with in-house expertise in systems design and development, and also one that is expecting to install a number of flexible manufacturing systems in the future. Developing an in-house capability in designing, installing and operating FMS can reduce subsequent FMS investment costs and can result in tremendous savings in maintenance and repairs.

FMS component manufacturers come from three groups of industrial firms: electrical and electronic engineering firms, computer and IT firms, and mechanical engineering firms. Figure XV compares the competitive strengths of some of the major component suppliers. The chart confirms that few companies have in-house capabilities in all the areas necessary to produce flexible manufacturing systems. The exceptions are a few Japanese firms - Fanuc, Hitachi and Toshiba - which have strong in-house capabilities in all three areas.

The past few years have witnessed a trend among major FMS component manufacturers to expand their activities, usually by acquiring specialised independent firms (see Figure XVI). Major electrical firms such as General Electric, Westinghouse, Siemens and NEC, and computer firms like IBM have established subsidiaries in robotics and computer-aided design. Many automobile manufacturers have done the same. However, except for Renault, Fiat and Toyota, no noticeable shift towards in-house production of machine tools has occurred despite the fact that many of these companies are major users of machine tools.

Most of the big machine tool manufacturers also produce computer-numerically controlled systems. In recent years several have expanded their activities to include production of industrial robots, computer-controlled material handling equipment, computer-aided manufacture and systems engineering. As yet they have not expanded into computers and telecommunications. They have, however, integrated their activities into areas on the borderline of electro-mechanical technologies.

Trends in machine tool production should in this connection be examined as machine tools make up the majority of pieces of equipment used in flexible manufacturing systems. Machine tools have not recorded any significant growth but changes are taking place in the composition and location of production. The proportion of numerically controlled machine tool production (in total machine tool production) grew from 1.7 per cent in 1967 to more than 50 per cent in 1981. In 1984 Japan, the FRG, the United States and the USSR accounted for nearly 65 per cent of the total world machine tool production of

$20.8 billion. While the shares held by the FRG and the Soviet Union have remained relatively stable, between 1975 and 1984 Japan increased its share from about 8 per cent to 22 per cent and the U.S. share fell from 18 per cent to less than 13 per cent. (UN/ECE, 1986, pp. 23-43)

Possible FMS developments, including component parts, are summarised below. The major objective is to increase speed and accuracy.

(a) Advances in machine tools are expected to lie in their ability to perform simultaneous functions, in their cutting speed and in their use of lasers, plasma, electron-beam and water-jet techniques.

(b) Control systems, sensor interaction and accuracy of robots will continue to improve. They will also become more mobile, moving between different locations on the factory floor while performing a variety of tasks.

(c) The use of automated guided vehicles for carrying robots and other tools as well as for quality control and cleaning is also a foreseeable trend.

(d) The ability of flexible manufacturing systems to operate with the minimum of human attention depends to a large extent on the development of automatic sensors that can monitor the location and condition of different tools and products as they go through the production process. Among the many types of sensors being developed are those for touch, vision, acoustic, torque monitors, lasers and co-ordinated measuring. A common feature is their being computer-controlled. Thus, a common language for sensor equipment, FMS and CAD/CAM should also be developed, enabling different parts to communicate with one another. (UN/ECE, 1986, pp. 166-169) In addition, a greater understanding of the production process is crucial to avoid deficiencies in the operating system.

(e) The development of new materials could create a demand for new types of machine tools since existing machine tools are designed for processing conventional materials like cast iron, sheet metal and aluminium.

FMS applications are still limited, cost being only one constraint. Production volume in many applications is still too low to justify the investment. Today, flexible manufacturing systems fill the niche between fixed automation systems used for high-volume production and stand-alone machine tools. Flexible manufacturing systems actually come into their own in mid-volume manufacturing, a variable amount that depends on the complexity of parts and the types of processes required to make them. Lack of expertise also inhibits widespread diffusion. Few potential users are skilled in all the technologies required to design and install a system, although some machine tool suppliers and some major users are beginning to develop the expertise. (Kinnucan, 1983, cited in Microelectronics Monitor, April-September 1984, p. 23)

Cost is the biggest barrier, but the price of not automating may be even greater. According to most forecasts, the diffusion of flexible manufacturing systems will be rapid over the next decade - not only within large but also within small and medium-sized companies - particularly in Japan. By the early 1990s many thousands of FMS are expected to have been installed.

B. Robots

The robot industry is relatively young. The first commercial use of robots was in the early 1960s but not until the mid-1970s did output reach a level warranting consideration of a separate robot industry. Since then the industry has grown rapidly, with an average yearly growth of more than 30 per cent in value and volume terms. Both new and established firms have entered the industry.

Despite these high growth rates, the robot industry remains limited. In 1982 total output was just 3 per cent of the total output of the machine tool industry. But its high potential for growth and its role in factory automation make the industry strategically important. Estimates of the 1990 world robot population range from a low of about 100,000 to a high of 1 million.

No exact record of the number of robot-producing firms is available. In 1983 Japan had about 250 firms (which includes 80 firms producing robots for the firms' own purposes alone); the United States had about 50; and Western and Eastern Europe as a whole also had about 50.

Most robot manufacturers, or at least the divisions within firms producing them, are relatively small. In 1982 total turnover was approximately $150 million. It would, however, be misleading to conclude that the mean turnover of the 50 producers was $3 million. In fact the industry is highly concentrated. In the United States, six firms account for about 80 per cent of total output. Similar high concentration rates are found in other countries. In Japan, 14 firms accounted for 65 per cent of total output; in the FRG, 10 firms accounted for 90 per cent; and, in Sweden, just one firm accounted for more than 80 per cent.

To produce robots, a firm must possess capabilities in a number of different areas including machine tools, computers, process control, sensors, software, welding, painting and assembly. This explains why established firms that have gone into robot production have their origins in a variety of industries (see Figure XVII). There are observable differences in the origins of robot manufacturers in the various producing countries.

In nearly all countries, robot use is limited to just a few applications. The first significant installations of industrial robots were in metal processing and fabrication, for example in hazardous areas such as foundries and casting. In the 1970s spot welding emerged as a major use for robots. The first robot welding line was installed at General Motors in 1969. More recently electronics assembly has emerged as a focus for growth.

In the United States, most firms that went into robot production in the industry's early days came from the mechanical engineering industry, usually machine tools and material-handling. By the end of the 1970s, large diversified companies, particularly those with in-house electronics capabilities, began establishing divisions for robot production. Many such firms, including Westinghouse and General Electric, entered the field by acquiring independent robot firms and through a complex network of manufacturing and sales licensing agreements.

The beginning of the 1980s saw the increase of robot-producing firms. They can be classified into two groups: Some, like General Motors and IBM were large enterprises. Being major robot users, they were able to learn all about robot production, thus deriving considerable competitive advantage. Others were new small firms with their backers usually possessing an electronics background. So far they have succeeded by concentrating their activities on particular segments of the robot industry such as assembly systems or vision systems.

In Japan, many firms have been in robot production since 1968. They had their origins in the machine tool industry and (unlike in the United States) in the computer and electronics industry. All are major conglomerates, with interests not only in computers but also in telecommunications and consumer electronics. Since the mid-1970s, Japanese firms have moved the quickest. Their pattern of use has been followed by the United States but with a lag of several years, with Europeans even further behind.

In Western Europe, robot manufacturers had their roots across a range of industrial sectors. One striking feature is that several car manufacturers such as Volkswagen, Fiat, Renault and Volvo are not only major producers of robots, they are also major users.

Table 29 presents information on selected robot manufacturers and their origins. While American manufacturers and, to a more limited extent, European manufacturers have been concentrating on producing highly sophisticated robots, the Japanese have been focusing on production of lower-cost equipment through close co-operation among themselves and with users and equipment suppliers. (UN/ECE, 1985, pp. 71-74)

Table 30 presents information on the sectoral use of robots for various OECD countries and Table 31 their distribution according to area of application. Until recently countries without a motor vehicle industry were unlikely to have large stocks of robots, particularly welding robots. In the future, given current growth rates, countries with a relatively large electronics sector are the ones most likely to experience a fast growth in robot population. This considerable expansion must be having an impact on the organisation of production. The next section turns to this issue.

C. Implications for the organisation of production

A recent assessment reveals that concepts of the factory of the future vary between countries. (*The Economist*, 30 May 1987, pp. 1-18) In the United States, emphasis is more on computer-integrated manufacturing. CIM or FMS in one form or another is being introduced in an estimated 96,000 factories. Already, a considerable amount has been invested. Between 1981 and 1986, U.S. firms spent nearly $50 billion installing the tools of flexible manufacturing. Firms, including General Motors, General Electric and IBM, have embarked on major CIM-like activities.

While the emphasis in the United States is on computer-integrated manufacturing, Japanese firms appear to have concentrated more on flexible manufacturing systems. This is partly because of a shortage of software skills in Japan and partly because of a difference in attitude; that is, one of automating a job shop rather than trying tc make a rigid transfer line become flexible. The Japanese attempts are considered to have been more successful. Japanese factories, compared with the American ones, have an average of 2.5 times as many computer-numerically controlled machines, 5 times as many engineers, and 4 times as many people trained to use these machines. With few exceptions, reports say, flexible manufacturing systems installed in the United States show an astonishing lack of flexibility. The technology is not to blame, add the reports; it is the management that makes the difference.

Though there are flexible manufacturing plants in Europe, the total is estimated to be not more than 50, while Japan, with half the population, is installing that number of FMS units annually. Though European firms are pursuing something similar to computer-integrated manufacturing, they prefer to call it advanced manufacturing technology (AMT). Under its ESPRIT programme on information technology, the EEC has spent $120 million of public money since 1982 developing ideas for the factory of the future and now has a proposal for CIM research totalling $1.3 billion over the next five years. On top of this, the Community plans to pour more than $900 million into communications research under its RACE programme, and $140 million has been allocated to its BRITE programme on industrial technologies. Then there are the national efforts on computer-integrated manufacturing run by individual European governments.

The development of computer-integrated manufacturing, flexible manufacturing systems and similar technology has important implications for global competitiveness. It should be stressed that computer-integrated manufacturing does not provide an off-the-shelf solution to solve what are really problems of poor management. Profitability is still the important criterion for the introduction of these methods. Firms need not spend more than $5 million or so to gain many of the benefits of switching a factory over to CIM-based production. But its introduction requires nothing short of a total overhaul of a company's strategy, involving managerial effort. Managers have to ask themselves searching questions about what products they expect to be making in five years' time, which technology they will be using, who will be their competitors, and how fast and at what price new flexible plants will be able to respond to signals of the marketplace. Investment in factory automation usually requires more skilled workers. Justifying CIM investment requires a careful scrutiny of the overheads and a look at some of the intangible benefits that can accrue. While firms that have installed FMS units are still accumulating experience, the number being installed around the world is doubling every two years.

One of the most powerful effects of the tremendous investment in factory automation, with its potential for changing the very nature of production, is that the factory is re-emerging as the focal point of corporate strategy. Eliminating direct labour costs is not the major objective; indeed, direct labour costs are not sufficiently large to justify these enormous investments. (In the United States, direct labour costs account for between 10 to 15 per cent of total costs.) Rather, the major benefits arise from the ability to automate the flow of information through a factory. Thus, the labour costs that are saved are those of indirect labour and middle management. More important savings are generated elsewhere. For example, flexible manufacturing systems do not make the same mistakes as people - quality control expenses fall dramatically. And, if automation is accompanied by the "just-in-time" approach to inventories of components and finished goods, another major cost element fades into insignificance. However, managers are not accustomed to thinking along these concepts. Besides, quantifying savings that result from a reduction in lead time is difficult.

Unless one is operating within a fully vertically integrated factory, some of these benefits can only be realised if all the companies involved in the production chain have systems that can communicate with each other. This partly explains an earlier observation - that more and more, small- and medium-sized firms are taking up flexible manufacturing systems. Big manufacturers in the United States are encouraging suppliers and sub-contractors to link up electronically. (Business Week, June 16, 1986, pp. 84-86)

The issue whether or not to internationalise producer services is another little-known area that is likely to have major implications. In the past, many producer services were carried out within the firm because it was believed that obtaining them from outside would result in prohibitive transaction costs. Information technology could lead to negligible transaction costs. However, firms may have internalised for other reasons - secrecy or difficulties associated with transferring information, for instance. Information technology may simply allow these firms to reduce internal costs of transferring information from one part of the organisation to the other.

The possibilities of, for example, the marketing department having immediate access to production data have not yet been fully realised. Both production and marketing have benefited separately from the introduction of information technology in various ways but their integration has not happened on a sufficiently large scale to enable the implications to be assessed. All too often companies have not pursued an integrated strategy; the lack of software and telecommunications standards can lead to problems not only in supplier-user communications but also in inter-organisational communications. This happens when each department in an organisation pursues its own automation strategy. Much remains to be learned about the impact of information technology on changing inter-organisational relationships.

The fact that benefits can now be gained from increased flow of information and increased co-ordination can be a set-back for developing countries. If they retained their contractual arrangements with assemblers in the developed countries, developing countries might not have access to the IT infrastructure (particularly in telecommunications) allowing them to participate in the integrated information and production flow. Also, if firms in the developed countries attempted to reduce their inventories (to either reduce warehouse expenditure or to smooth the flow through the factory), then even if transport costs were unimportant, a high premium would be placed on reducing transport time. Thus, the production chain would tend to be located within closer geographical proximity.

On the positive side for developing countries and for small economies in general, flexible manufacturing systems are precisely that: flexible. Short-batch production becomes economic. The whole notion of economies of scale could be turned on its head. Flexible manufacturing systems make it possible to produce different products, along a certain continuum, using the same equipment.

Some developing countries such as China, the Republic of Korea and Singapore have started using industrial robots. A robot R&D centre is being constructed in China, and Shanghai factories are reported to be producing robots. The first aim of the recently formed Singapore Robotics Association, which has 25 corporate members so far, is to promote the use of robots in Singapore to ensure the competitiveness of the country's products and services.

Scale constraints have been cited as a major obstacle to industrialisation in developing countries. Increasing competitive pressures in domestic and world markets have stimulated efforts in many industries to gain the perceived advantages of large plant size through building progressively larger operating units. A tendency towards industrial concentration in both industrialised and developing countries has been a feature of the "fourth long wave" and has been apparent in manufacturing - particularly in chemicals, steel and automobiles - as well as in power generation, mining and agriculture. At the same time the perceived disadvantages of concentration and size have led to increased efforts to find technological solutions allowing profitable production at lower levels.

Flexible manufacturing systems and their less comprehensive cousins are diffusing into an ever wider range of industrial sectors and applications. The ways in which they do so will be crucial at both national and international levels. A number of questions arise: What will displaced production workers do after the successful introduction of flexible manufacturing systems? Are some countries moving rapidly towards a post-industrial society? And, of considerable importance for patterns of international trade: Will workerless factories (which would have resulted in production to be relocated back to the industrialised countries) lead to a loss of export earnings for the developing countries?

While the possibility of small batch production and strengthening international competitiveness are factors of advantage to developing countries in the adoption of flexible manufacturing systems, indiscriminate imports of capital-intensive automated systems with little scope for employment will clearly not be in the interests of many developing countries. But such imports are a distinct possibility since new generations of capital-goods equipment and systems produced by developed countries will be increasingly automated. At the same time a "technological gap" in industrial organisation and production techniques will have adverse consequences for developing countries, particularly on the export front. In this connection it is important to remember that the advances in manufacturing technology essentially involve the building up and operation of systems. Hence the capacity to disaggregate systems, select and buy the components or sub-systems, and to build systems according to one's choice and requirements becomes crucial for developing countries. Building up such a capacity should be an important objective of their industrialisation efforts.

Notes

(1) A variety of estimates is presented in UN/ECE, 1986, pp. 23-43.

(2) This includes CAD/CAM, CIM and other computer-based systems but it excludes stand-alone machine tools, whether or not they are numerically controlled.

Table 28. U.S. investments in shop-floor automation

	1980	1985	1990*
	(millions of US dollars)		
factory computers and software	935	2861	6500
materials handling systems	2000	4500	9000
machine tools and controls	3000	4800	7000
programmable controllers	50	550	3000
robots and sensors	68	664	2800
automated test equipment	800	2000	4000
Total spending	6853	15375	32300

Source: Business Week, 16 June 1986, p. 86.

* estimate

Table 2[illegible]. Selected major robot manufacturers and their origin

Western Europe	United States	Japan
Automotive:		
Volkswagen (FRG)	General Motors	Toyoda (Toyota)
Fiat Comau (Italy)	Fanuc	
Renault (France)	(GMF) Robotics	
Volvo (Sweden)		
Electrical machinery, electronics, computers; including conglomerates with electronic capabilities:		
ASEA (Sweden)	IBM	Hitachi
livetti (Italy)	Unimation (Westinghouse)	Matsushita Electric
Siemens (FRG)	General Electric	Toshiba
DEA (Italy)		Yaskawa Electric
		NEC
		Fujitsu Fanuc
		Mitsubishi Electric
		Fuji Electric
Mechanical engineering: machine tools, material handling, process technology etc.:		
Kuka (FRG)	Cincinnati Milacron	Kawasaki Heavy Industries
Trallfa (Norway)	Bendix	
	Prab Robotics	

Source: United Nations/Economic Commission for Europe, Production and Use of Industrial Robots, E.84.II.E.33 (New York, 1985), p. 122.

Table 30. Use of robots by industry in various OECD countries

(percentage distribution based on number of units)

USE OF ROBOTS BY INDUSTRY IN VARIOUS OECD COUNTRIES
(Percentage distribution based on number of units)

CANADA (1981)	
Automobiles	63%
Plumbing Fixtures	9%
Electrical Engineering	6%
Metalworking	6%
Appliances	5%

GERMANY (1981)	
Transportation Industry	46%
Electrical Engineering	14%
Mechanical Engineering	12%
Metal-Working Industry	6%
Plastic and Materials Industry	6%
Other	16%

ITALY (1979)	
Automobiles	28%
Household Appliances	8%
Metal Industries	8%
Electrical Industry	6%
Rubber Industry	1%
Exports	49%

NETHERLANDS (1982)	
Metal Working Industry	64%
Mechanical Engineering	12%
Electrical Engineering	9%
Transport Equipment	5%
Construction materials	3%
Rubber and plastics	1%
Others	6%

SWEDEN (1979)	
Metal Working Industry	51%
Mechanical Engineering Industry	15%
Transportation Industry	22%
Electrical Engineering	9%

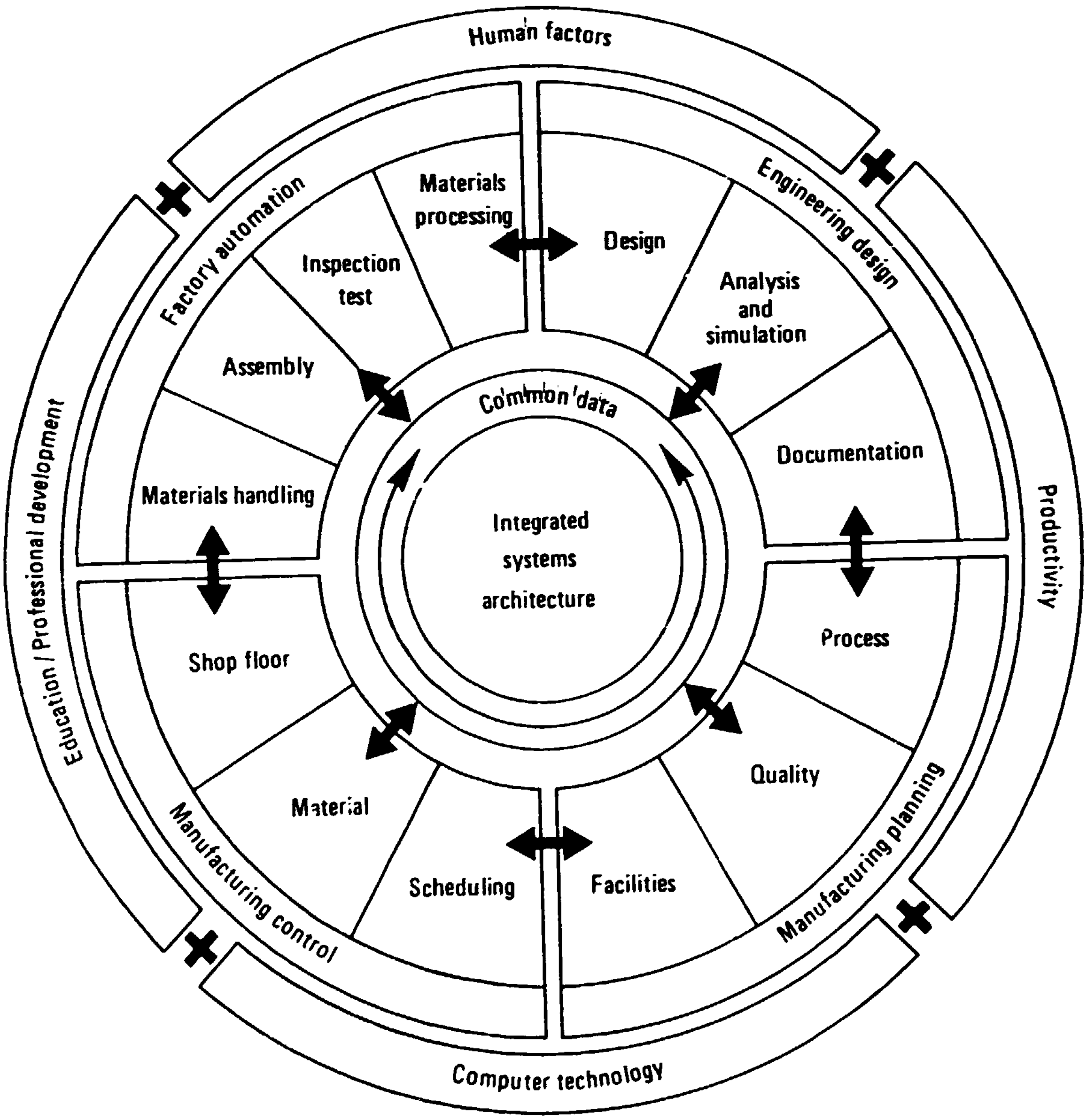
Sources: Canada - National Research Council, Canada; FRG - KUKA, quoted in Wirtschaftswoche Nr. 15, 1983; Italy - Le Progès Scientifique, March-April 1981; Netherlands - Stichting Toekomstbeeld der Techniek; Sweden - Swedish Electronics Commission; cited in K. Flamm, International Differences in Industrial Robot Use: Trends, Puzzles and Possible Implications for Developing Countries, World Bank Discussion Paper, Report No. DRD185 (Wash., D.C., 1986), p. 24A.

Table 31. Distribution of robot use by application, various countries

Application	Year	Spot Welding	Arc Welding	Painting /Coating	Finishing	Assembly	Loading /Unloading	Material Handling	Casting	Other	Total
Percent Distribution:											
	Year:										
Belgium	1982	71.80		7.21		1.31	11.15	3.28	.66	4.59	100.00
	1983	46.69	8.75	3.70	.97	.78	11.67	2.53	.39	24.51	100.00
	1984	60.00	7.33	N/A	.70	.47	8.37	2.44	N/A	N/A	100.00
France	1983	27.86	12.49	7.31	2.24	6.97		-------34.53---------		8.61	100.00
Germany	1982	44.56		9.70		2.84	4.49	13.65	2.79	21.98	100.00
	1983	32.50	17.83	12.21	.46	5.17	6.67	4.04	2.75	18.39	100.00
	1984	28.70	23.21	11.62	.33	6.83	7.06	3.18	2.23	20.42	100.00
Italy	1982	44.73		8.82		10.09	9.27	---9.09---		18.00	100.00
	1983	35.00		10.00		10.00		----------25.00---------		20.00	100.00
Japan	1982	25.24		3.36		19.12	8.08	21.31	1.75	21.15	100.00
Japan	1983	14.07	14.62	3.53		26.02	8.94	24.76	2.52	5.53	100.00
Sweden	1982	17.93		16.90		1.03	40.00	8.97	13.10	2.07	100.00
UK	1982	40.94		15.86		1.84	9.62	8.70	5.53	17.50	100.00
	1983	19.91	13.35	9.53	1.54	5.88	9.41	23.50	2.97	13.92	100.00
	1984	19.37	14.02	7.28	1.77	8.18	8.76	23.97	2.22	14.43	100.00
US	1982	38.94		7.78		1.14	16.83	20.63	13.89	.79	100.00
US	1983	24.14	10.65	2.82	2.16	16.22	8.33	-----26.23----		9.44	100.00

Source: RIA, Worldwide Robotics Survey and Directory, various years; BRA, Robot Facts, various years; cited in K. Flamm, International Differences in Industrial Robot Use: Trends, Puzzles and Possible Implications for Developing Countries, World Bank Discussion Paper, Report No. DRD185 (Wash., D.C., 1986), p. 22A.

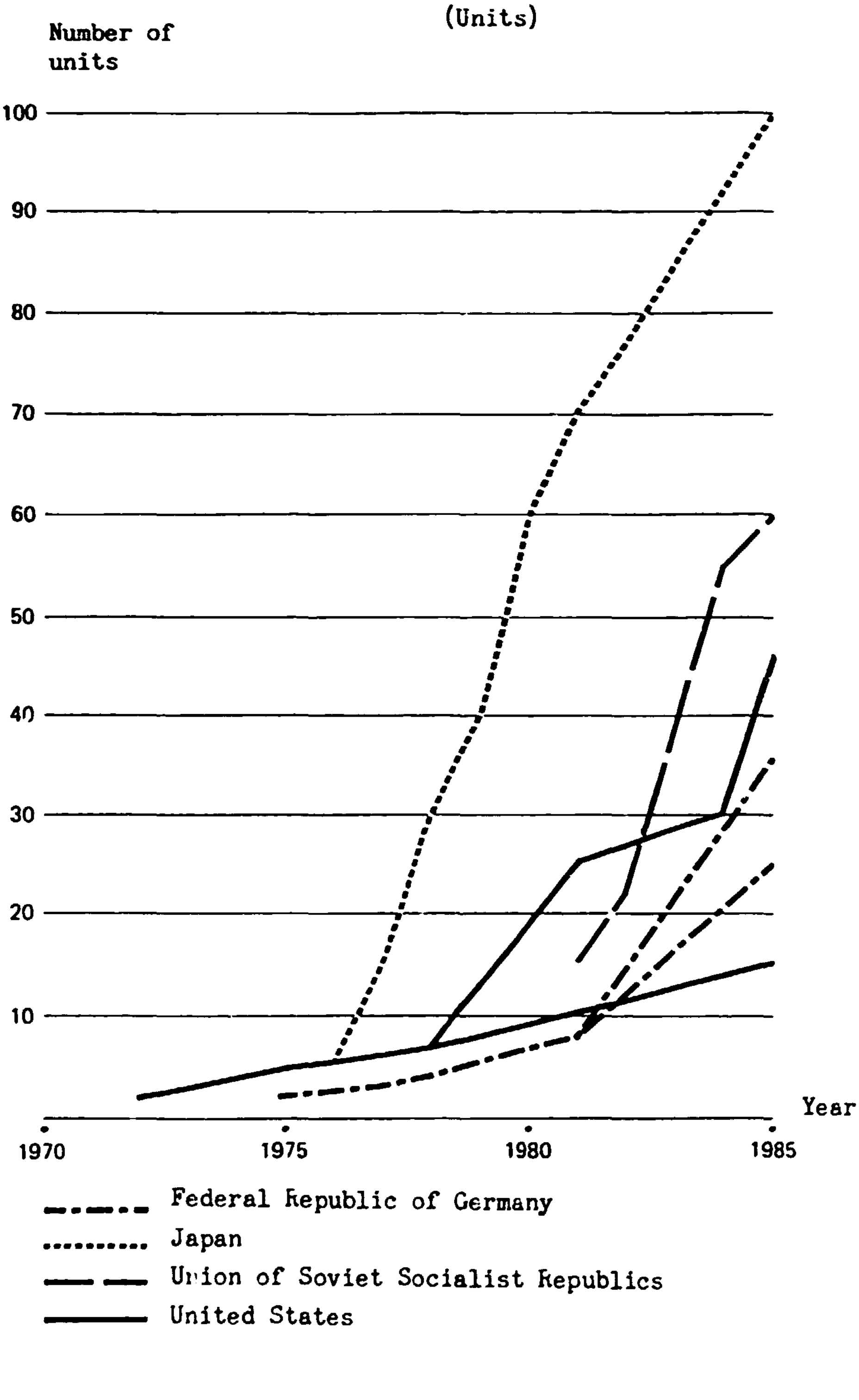
Figure XIII. Model of a CIM system



Source: United Nations/Economic Commission for Europe, Recent Trends in Flexible Manufacturing (New York, 1986), p. 21.

Figure XIV. Growth of FMS in the FRG, Japan, the United States and the USSR

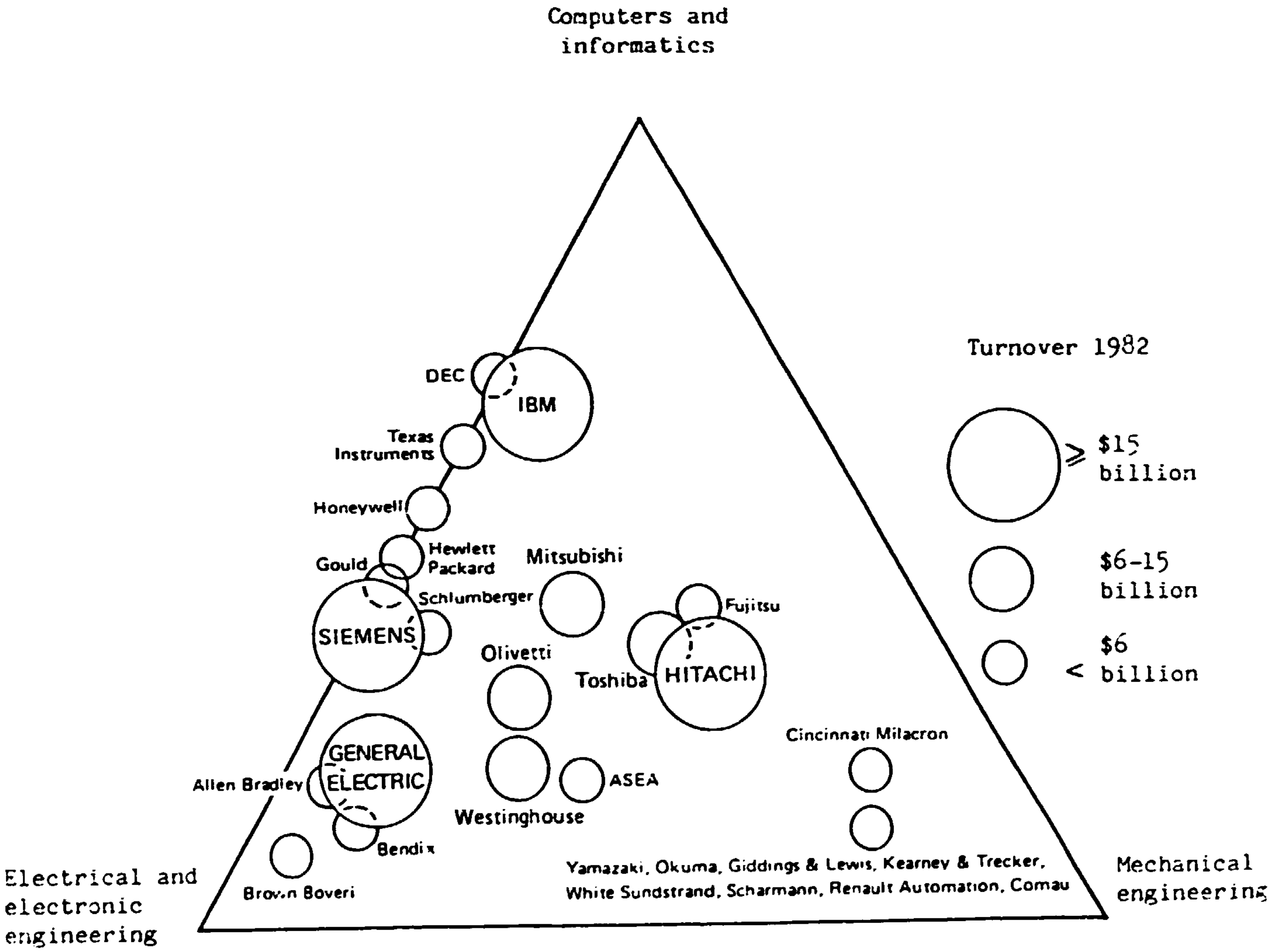
(Units)



Source: United Nations/Economic Commission for Europe, Recent Trends in Flexible Manufacturing (New York, 1986), p. 29.

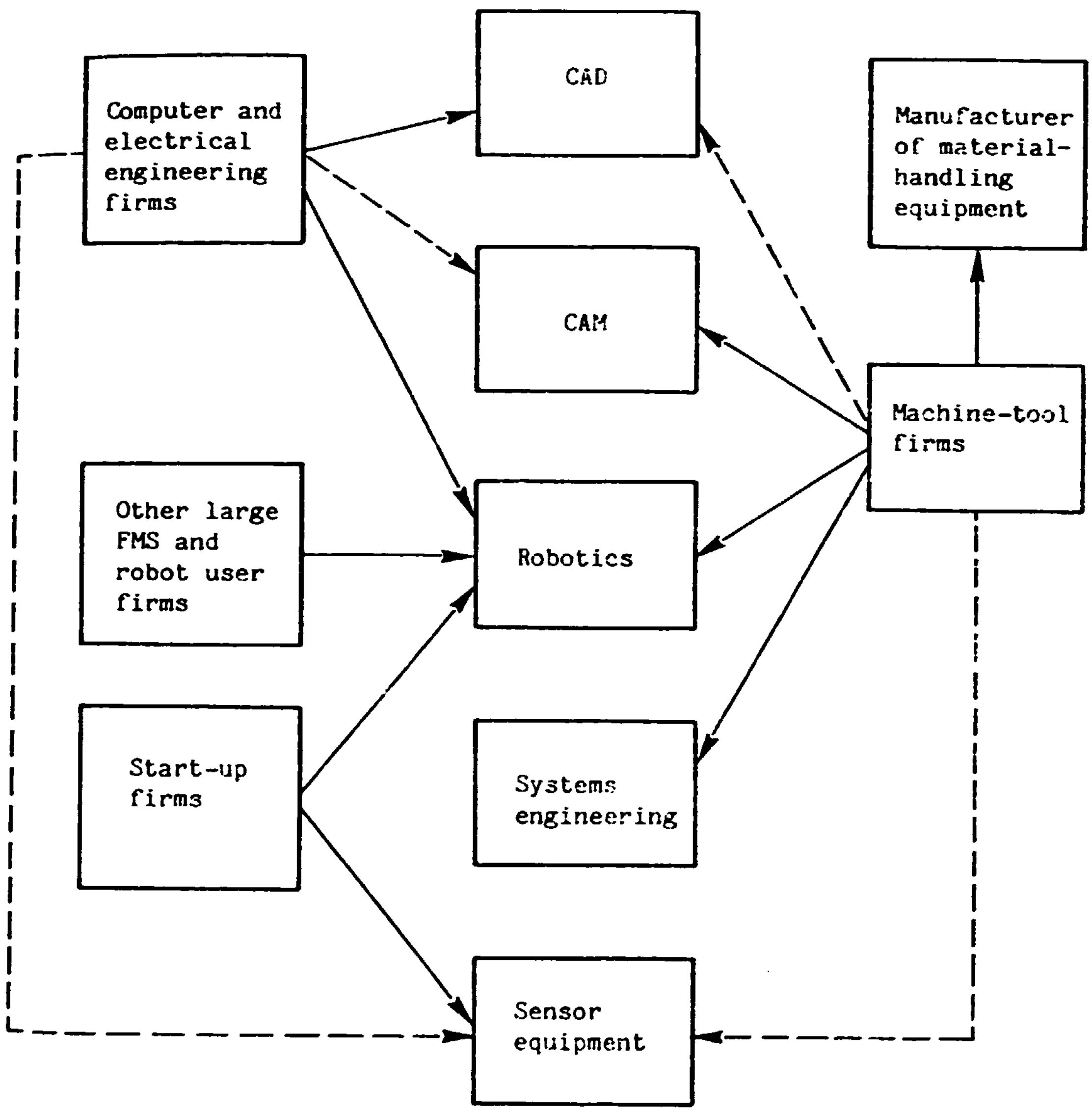
Note: The two curves for the United States apply to a wider and a stricter definition, respectively, of FMS. For the FRG, an interval estimate is given for the number of FMS installed at the end of 1984.

Figure XV. Some of the major suppliers of automation equipment and their relative competitive strength in the areas of mechanics, computers and electrical engineering



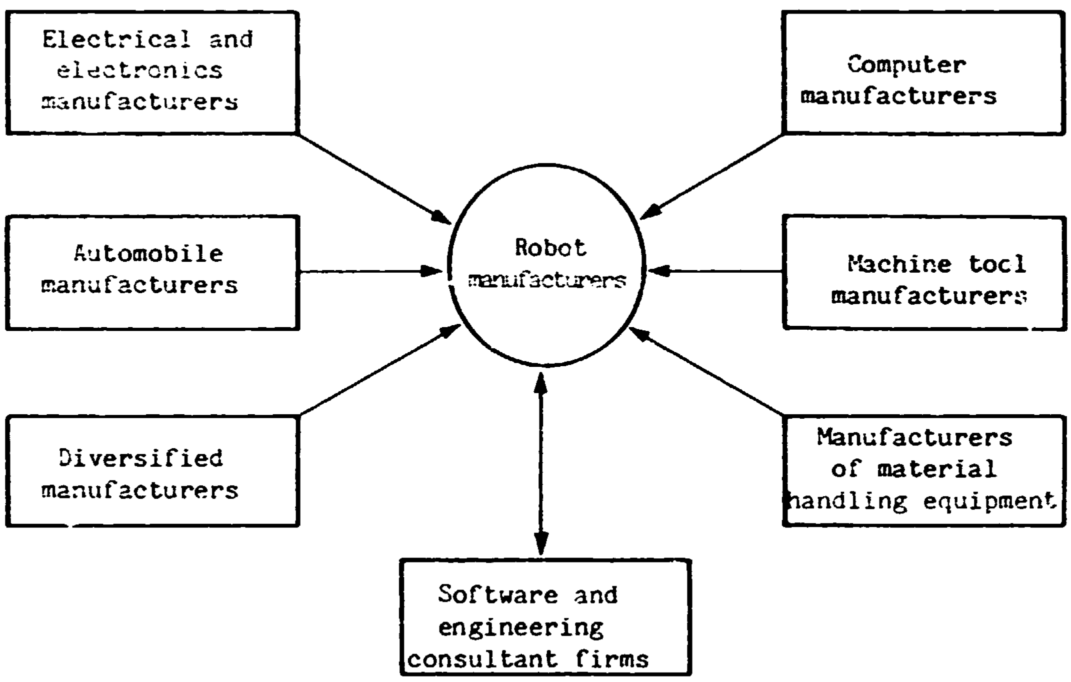
Source: United Nations/Economic Commission for Europe, Recent Trends in Flexible Manufacturing (New York, 1986), p. 72.

Figure XVI. Major trends of integration among manufacturers of FMS components



Source: United Nations/Economic Commission for Europe, *Recent Trends in Flexible Manufacturing* (New York, 1986), p. 73.

Figure XVII. The industrial origin of robot manufacturers



Source: L. Conigliaro, "Trends in the Robot Industry (Revisited): Where are We Now?", Proceedings of the 13th International Symposium on Industrial Robots (Chicago, April 1983), cited in United Nations/Economic Commission for Europe, Production and Use of Industrial Robots (New York, 1985), p. 122. (E.84.II.E.33)

V. TECHNOLOGY FLOWS

The process of technology transfer is of utmost importance particularly for firms and countries that see themselves as falling behind the state of the art. Acquiring technology already developed by others is a means of catching up. Technology can be transferred through:

(a) trading products including machinery and process equipment, either individually or as part of a turnkey package; either arrangement can embody technical knowledge;

(b) subsidiaries, affiliates and joint ventures with local firms;

(c) licensing or sale of patents and other industrial property rights and know-how, with the latter including technical or management assistance; and,

(d) databases, scientific literature and published patent specifications.

During the 1960s and 1970s, international organisations and host country governments devoted a great deal of attention to the issue of whether or not foreign direct investment - item (b) above - actually transferred technology. Many transnational corporations established facilities in different countries to reduce transport costs and to take advantage of lower input costs, at the same time continuing to generate new technical knowledge in their home countries. Host countries gained at best only an operating knowledge of the technologies used. Often, firms in the host country were tied to the TNC through the technology. Patents figured in this scenario because they provided a mechanism whereby firms could repatriate their profits. In countries with strict foreign exchange controls, royalty payments were in fact a legitimate mechanism of transferring earnings out of the country.

While this issue remains important, attention has shifted in recent years to the role of the technology recipient. The transfer of technology on right terms and conditions and strengthening the negotiating capacity of the recipients in this respect assumed importance. Now firms in host countries would like to be in a position of further developing the technology themselves, appropriate to their own needs and commercial interests. This does not mean an end to the role of imported technology (in fact, some of the more successful economies run their technology account at a deficit) but it does mean that host country firms must define their needs more clearly and ensure adequate infrastructural support to absorb the technology.

This chapter analyzes the indicators of two modes of transfer - (b) and (c) above - relative to flows between countries or different groups of countries, and where possible, relative to the changing volume of flows in different sectors. As with the S&T indicators discussed in Chapter I, no single indicator captures all aspects of technology transfer. The OECD has expended considerable efforts (1) to generate internationally comparable technological balance of payments (TBP) data, which includes payments arising from licenses, patents, trademarks, designs, copyrights, use of technical know-how and technical assistance. Not reflected, of course, is technological knowledge embodied in products and technology provided to affiliates or subsidiaries, unless royalties are paid. These two factors, it is argued, provide far more technlogical knowledge than the activities monitored by TBP data. On the other hand, data on both trade and investment flows reflect far more than simply technology flows. All these indicators exclude non-commercial transactions such as the use of libraries.

A. Foreign direct investment

The level of foreign investment undertaken by transnational corporations responds to a variety of forces including corporate strategy, policies adopted by both home and host countries, and by the general economic climate. During this decade the interaction of these variables has, overall, not been favourable to the growth of foreign investment. The fast-moving technological climate in recent years is an example of a variable that is having contradictory effects. On the one hand, information technology allows corporations to integrate their activities to an amazing extent and to scan the world economy rapidly for profitable opportunities. On the other hand, recent changes in production technology tend to discourage worldwide sourcing, encouraging instead the location of production closer to final markets.

Policy variables are also having uncertain effects on foreign investment. As a result of concerns articulated during the preceding two decades, host countries have been attempting to minimise the negative effects of foreign investment. At the same time, because of growing balance of payments problems, foreign investment is increasingly seen as potentially capable of easing foreign exchange constraints and as assisting the development process. Policy measures of home country governments also determine the course of foreign investment. The seemingly irreversible tide of protectionism in industrialised countries has made export-oriented investments in developing countries less attractive and has directed investment funds towards the protected markets.

The fast growth of foreign direct investment during the 1970s came to a sudden halt in the early 1980s (see Table 32). Perhaps the greatest factor affecting foreign direct investment during the 1980s has been the unsettled world economic situation - the steep recession followed by an uneven recovery. The recovery has occurred mainly in the United States and in a few countries in South-East Asia. Interest rates have not helped - contrary to what would normally be expected during an economic recession - by rising steadily to a range of 3.5 to 8 per cent by the end of 1984. (UNCTC, 1985, pp. 3-6)

Between 1981 and 1983, flows into western industrialised countries fell by almost one-quarter and flows into developing countries fell by almost one-third. Each of these trends will be discussed below.

1. <u>Developed market economy countries</u>

Table 32 shows that more than 75 per cent of investment flows are into industrialised countries. Between 1982 and 1984, more foreign direct investment went to the United States than to all other OECD countries combined. Canada, France, the FRG, Japan, the Netherlands and the United Kingdom were individually the source of more investment funds than was the United States. This is quite different from the picture in the early 1970s when the United States was the largest source and the FRG, the United Kingdom and the United States were equally important as destinations.

Three main reasons explain the heavy flow of foreign direct investment into the United States.

(a) Many European and Japanese firms have expanded internationally on the basis of solid technological, production and marketing abilities.

(b) Economic growth has been strong in the United States since 1982, thus attractive to foreign investors.

(c) Access to a large market and avoidance of trade restrictions continue to be motives for foreign investment.

The ensuing competition from foreign firms has led to the introduction of new techniques and modes of organisation, in turn helping transform U.S. industry, particularly automobiles, chemicals, steel and electronics.

At the same time, investment flows from the United States have declined and flows from subsidiaries to their U.S. parents have increased. The latter has no doubt been influenced by the growth prospects of the U.S. economy compared with other countries. Relatively high interest rates and the appreciation of the U.S. dollar have been significant factors as well.

These developments do not necessarily suggest that the transfer of U.S. technology to other countries has slowed down. Investment flows do not represent precise technology flows since investment covers other items and since technology can be transferred through other means. Because of the high interest rates in the United States, local borrowing may have been utilised increasingly to finance capital investment and R&D activities by U.S. subsidiaries in foreign countries. (Vickery, 1986, pp. 40-44)

2. Developing countries

Only a quarter of foreign direct investment flows to developing countries. The industrialising countries of South-East Asia are now the leading recipients of foreign direct investment among developing countries. Since 1983 large investments, particularly in electronics, have flowed into Malaysia, the Republic of Korea, Singapore and the Province of Taiwan, which have relatively liberal foreign investment regimes. So is the case with China. Foreign investment and, more generally, capital investment has fallen sharply in Latin America where domestic demand has declined and imports have been curbed in an effort to reduce external indebtedness. In response to these pressures, foreign investment is generally going through a period of rationalisation and restructuring. (Vickery, 1986, p. 45)

Prospects appear to vary between sectors. For countries hoping to attract foreign participation in order to develop their petroleum industries, the key variable is future oil prices. Reduced oil consumption in industrialised countries may represent a permanent response to higher oil prices, but at the same time the recent plunge of oil prices has released significant amounts of technical expertise and capacity. In many non-fuel mineral markets, current world production capacity far outstrips demand.

In general, prospects for foreign direct investment in the manufacturing sectors of developing countries do not appear to be as buoyant as in the past despite moves towards liberalisation in at least some countries. Factors threatening to reduce investment flows include Latin America's continuing debt crisis, industrialised country protectionism, and TNC use of technologies that can discourage export-oriented investment. On the other hand, manufacturing sectors in developing countries are likely to continue growing more than in industrialised countries and competitive advantage may shift in favour of developing countries. Indeed, in the long term the manufacturing sector will probably continue to attract direct foreign investment flows and may well see its share in total flows to developing countries continue to rise in the remainder of the decade. (UNCTC, 1985, p. 80)

Service-oriented activities will continue to be the most dynamic recipient sectors. Initially this grew out of the internationalisation of manufacturing, which required services. Once established, international service companies probably found that they could offer a broader range of services than could local competitors and that they could provide local manufacturing companies access to international marketing techniques. Other more general developments contributing to the growth in transnational service corporations were the expansion of trade in goods and services, the rise in international lending, labour migration and the growth in tourism. These developments would not have been possible without the rapid progress in communications, including transportation, which stimulated the need for other international services such as lodging, banking and insurance. The expanded availability of telephone, telex and data transmission have had a profound impact on both trade and foreign direct investment. Deregulation of certain services in some countries has also accelerated their internationalisation. Working against these factors for growth, however, are the new technological developments. Although these enable an increase in the tradability of services, they simultaneously decrease the need for foreign direct investment. The rapid growth in foreign direct investment in services over the past 25 years may therefore not be repeated in the future. (UNCTC, 1985, pp. 86-88)

It has been pointed out that a combination of domestic and international policies that would ensure a revival of economic growth in the developing world is likely to be more effective in encouraging larger flows of foreign direct investment than a unilateral relaxation of policies towards foreign direct investment and TNCs in host countries. It is also cautioned that foreign direct investment cannot be seen as a panacea in either a qualitative or a quantitative sense. Relatively few developing countries benefit from foreign direct investment; in particular, TNCs tend not to invest in either the low-income or least developed countries on a scale that can make any significant contribution to those countries' recognised external resource needs. With very few exceptions, countries at the lower end of the per capita income scale are unlikely to attract foreign private capital into the types of activities that are necessary for their future development. (UNCTC, in the CTC Reporter, Spring 1987)

B. Technological balance of payments (TBP)

Many countries collect information on payments and receipts for patents and related items - the most direct measure of technology flows between firms and countries. However, data from different countries are not always comparable. Sometimes these are culled from R&D surveys, other times from balance of payments figures. Parent-subsidiary transactions, exchange rate fluctuations and tax regimes also affect the data. TBP data may reflect economic and financial rather than technological relations between countries. And there may exist agreements to supply or to trade technology in which no financial exchanges are involved.

International payments for patents, licenses and technical know-how have risen, in constant terms, from $9.7 billion in 1975 to $11.4 billion in 1983 for 14 OECD countries (2). (Vickery, 1986, p. 27) While small especially compared with the value of world trade and foreign direct investment (also, production under independent licence agreements is estimated to be approximately 5-10 per cent of production from foreign direct investment), the amount is not insignificant, it is growing, and it more closely depicts "technology" transactions than do either of the measures discussed earlier. A large share of technology trade, which is dominated by multinational firms, is in R&D-intensive industries. An increasing share of this trade is between associated firms. (OECD, STI Review, Autumn 1986, p. 79)

Before a discussion on the transactions among developed countries and between developed and developing countries, it is worth pointing out that a surplus in a country's TBP account does not necessarily indicate technological strength, nor does a deficit necessarily indicate that a country is lagging behind. Most countries are net importers of technology. A more telling indicator is the ratio of technology payments to domestic R&D. The five major OECD countries (3) spend less than one-fifth of their business enterprise R&D efforts on purchasing technology from abroad. Spain and Portugal, however, spend up to 150 per cent more on the purchase of foreign technology than on their own R&D. (OECD, 1986, p. 19)

1. Developed market economy countries

The United States is easily the largest exporter of technology. Not only does it have the largest share of total receipts, it also has a high TBP surplus. Switzerland and the United Kingdom are the only other countries with consistent surpluses, although on a much smaller scale than the U.S. In addition, all three countries have large stocks of overseas direct investment. France, the FRG and Japan are also major sources of technology but are not net exporters.

Canada, Japan and the United Kingdom together account for almost half of U.S. technology receipts. In recent years, Japan's ranking as an importer of U.S. technology has been going up, while the position of Europe and the developing countries has been declining. Between [illegible]8 and 1978, the proportion of U.S. know-how going to developing [illegible]ies fell from 25 to 20 per cent. (Ledic and Silberston, 1986, p. 108)

Japan's role as a technology supplier has grown. Its receipts from technological exports have increased in real terms, as have those of France. In 1983 Japan earned as much from its technology sales in absolute terms as did the United Kingdom and almost twice as much as did the FRG. (OECD, 1986, p. 19)

Japan has demonstrated the positive contribution that imported technology can play. The country has been a major importer of foreign technology, with 91 technology import contracts in 1950-54 rising to 1,569 in 1975-79. (Hiraoka, 1985, p. 234) At the same time Japan has intensified its R&D efforts to fully utilise and improve upon imported technology. Figure XVIII shows the fall of technology imports from 25 per cent of the value of R&D expenditure in the early 1970s to less than 10 per cent in 1983. The same phenomenon is happening in Canada largely because of increased R&D expenditure in the aircraft, communications and petroleum industries. Payments for technology have dropped from 30 per cent of R&D in the 1970s to 20 per cent. (Vickery, 1986, pp. 30-31)

2. Developing countries

Comprehensive TBP data for developing countries is not easily available. Developed country data do provide an indication. As mentioned in the above section, only 20 per cent of U.S. technology receipts come from developing countries. Most of the other developed countries also reflect a similar proportion for developing countries. The exception is Japan: One-half of its technology exports go to developing countries, primarily in Asia (as is the same unusual case for its foreign investment). Table 33 presents figures for the FRG. Developing countries accounted for less than 1 per cent of FRG expenditure during the 1970s, whereas receipts from them accounted for between 18 to 30 per cent.

From the point of view of the supplier countries, therefore, transactions with developing countries appear to be relatively insignificant. For the developing countries, however, the absolute amounts involved are quite considerable; in addition, a large proportion of the transactions take place between affiliated firms. Concern over this situation was expressed by, and on behalf of, developing countries. During the 1970s many Latin American countries introduced various regulations and controls designed to limit international payments for technology, improve the bargaining position of local firms and "unpackage" the various components of technology agreements. Over the course of the decade, receipts from Latin America to the FRG, Japan, the United Kingdom and the United States slowed down. At the same time, direct investment in Latin America except from Japan grew at a faster rate than technology receipts. Payments for technology did decline, possibly as a result of the new controls, but whether or not the technology transfer process was hindered is not clear. Latin American countries were extremely active in the international money markets, and the borrowings may have been used to import capital equipment. (Ledic and Silberston, 1986, p. 112)

A recent survey on the role of industrial property rights in TNC strategies has revealed that when TNCs license patents, they are primarily concerned with provisions that are technically related and provisions that deal with royalty payments such as the supply of additional know-how, granting of reciprocal patents, rights over improvement patents and training. These provisions were implemented more frequently than those touching on territorial restrictions on exports and restrictions on input purchases, output or sales. (Wyatt and others, 1985, p. 210)

Through its Technological Information Exchange System (TIES), UNIDO has been monitoring information on technology transfer policies, institutional arrangements and technology flows. Chapter VI presents some of the policy-related material. Some information on the types of collaboration entered into by developing countries and the country of origin is presented below.

Figure XIX shows that approximately 50 per cent or more of the technology transfer contracts concluded by a set of countries involved transmission of know-how, and licensing, sale or assignment of trademarks. For Egypt, however, the latter item was less than half than it was for the other countries. Patent licensing occurs only in about 6 per cent of the cases except in the Philippines where it accounts for about 17 per cent of the number of contracts, and in Peru, where it is just 1 per cent. Again with the exception of Egypt, while contracts involving management assistance account for about a third, both engineering and management assistance are included in at most 10 per cent of the contracts. Technical services, mostly for training local personnel, range from 5 to 30 per cent. (UNIDO, 1985, ID/WG.454/5, p. 31)

The United States and EEC member countries account for approximately 73 per cent of the technology transfer contracts. The United States would appear to have played an even more important role but for the inclusion of Spain and Portugal as host countries. (In these two countries, other Western European countries play the leading role.) Egypt concluded 20 per cent of its contracts with Japan, far above the Japanese average of 5.3 per cent. (UNIDO, 1985, ID/WG.454/5, p. 36)

3. Sectoral patterns

More than 80 per cent of international technology transactions take place in manufacturing industries particularly in chemicals; electronics and electrical engineering; non-electrical machinery; automobiles; transport equipment; and professional, scientific and industrial instruments and controls. Within OECD countries, agreements relating to technology for commercial and distribution services also exist.

In many countries the share of research-intensive or high technology industries in TBP is increasing especially since the electronics, telecommunications, information processing, aerospace and pharmaceutical industries are expanding internationally. This has happened most dramatically in Canada, France, Japan and the Republic of Korea, reflecting a structural shift towards the high technology industries. The trend is weaker in other countries, although nowhere is there evidence - at least in the countries for which detailed data are available - of any major shifts towards less research-intensive industries. (Vickery, 1986, p. 32) Technology trade between independent firms is predominantly in traditional industries, or industries with many small firms.

TIES data show that the majority of technology transfer contracts concluded with developing countries are related to manufacturing, many in chemicals, fabricated metal products, machinery and equipment (see Table 34).

4. Relations between firms

The transactions under discussion here take place usually between associated firms (see Figure XX). For example, in the case of the United States:

(a) payments of fees and royalties are predominantly from affiliates to U.S.-based parent companies;

(b) payments include parent company expenditure for R&D, administration and provision of business services;

(c) in 1983, 93 per cent of payments from Canada were to parent firms; and,

(d) in 1983, 87 per cent of payments from both the FRG and the United Kingdom were to affiliated firms.

Payments by U.S. and U.K. firms are more evenly split between affiliated and non-affiliated firms. Payments by Japanese and Swedish firms are less influenced by corporate ties, reflecting the relatively low levels of foreign direct investment in these two countries. (Vickery, 1986, pp. 34-35)

The general trend since 1970 (again, see Figure XX) is that corporate links are becoming an important basis for technology trade, particularly in electrical and electronic engineering and computers. In research-intensive industries, firms tend to operate through subsidiaries. This is also true for more traditional industries that are dominated by TNCs such as food, drink and tobacco and rubber products. Smaller firms in textiles and metal-working are more likely to license their technology to firms in foreign countries. (Vickery, 1986, pp. 35-36) A recent survey of TNC licensing patterns found that TNCs grant licenses most frequently to subsidiaries, other TNCs and affiliates. (Wyatt and others, 1985, p. 209)

C. Role of recipient firms

A great deal of the analyses of Japan's post-war success has focused on the build-up of its capital stock through joint ventures, licensing, foreign direct investment, as well as through its own capital investments. In addition, however, Japan invested heavily in its human resources. Although difficult to measure, the impact of education, on-the-job training and immigration on Japan's economic and technological success should not be underestimated. For instance, Table 35 shows that the Japanese work force has been characterised by a growing number of engineers (20 per cent of undergraduates) even when compared with the United States (4 per cent of undergraduates). Japan is also strongly committed to in-house training.

It could be argued that technology transfer in high technology industries is taking place through affiliated firms because the technology owner seeks to capitalise on its technological advantages before these are imitated (a process with an increasingly short time lag). Doubtless, this is part of the story. This argument arises out of the perception that technology is expensive to produce but is costless to transfer and that therefore, firms must internalise their technological advantages. This theory rests on dubious assumptions about the nature of technology as a discrete object which, if the price were right, can be transferred easily. So, negotiating the right price becomes the focus of attention. In reality, however, developing a technological capability is much more complex. In fact technology may be internalised not solely to earn huge profits but precisely because it is so difficult to externalise.

Some of the misunderstanding arises because the center of the policy debate is referred to as being one of "technology transfer". The term implies a one-way flow from firms with the technology to those without it. Actually, the issue is one about the process of acquiring and accumulating a technological capability. Attention is now shifting, as it should, towards this broader issue.

Notes

(1) Part of this process included bringing together experts from 19 countries in December 1981 to examine 19 papers. Since then, OECD's Science and Technology Directorate has attempted to collect and analyse TBP data for its member countries. Results have been obtained for the Federal Republic of Germany and France. Financial constraints have, however, delayed analysis of the data for the other countries, although the OECD does have access to the national statistics.

(2) Australia, Austria, Belgium/Luxembourg, Canada, Federal Republic of Germany, France, Italy, Japan, Netherlands, Spain, Sweden, United Kingdom and United States.

(3) Japan, Federal Republic of Germany, France, United Kingdom and United States.

Table 32. Market economies: gross inflows of foreign direct investment, 1970-1983

(percentage)

	World market economies	Developed market economies	Developing market economies
Average annual growth rates [a]			
1970s [b]	16.8	16.4	18.0
1980-1981	14.3	12.6	19.2
1982-1983	-13.2	-11.8	-17.0
Share in total flows			
1970-1971	100.0	77.1	22.9
1980	100.0	77.6	22.4
1981	100.0	71.9	28.1
1982	100.0	67.0	33.0
1983	100.0	74.3	25.7

Source: UNCTC, Trends and Issues in Foreign Direct Investment and Related Flows, A Technical Paper, E.85.II.A.15 (New York, 1985), p. 8.

Table 33. FRG: receipts and expenditure on patents, inventions etc.

(percentage)

	Industrial countries		Developing countries		Centrally-planned economies	
	Receipts	Expenditure	Receipts	Expenditure	Receipts	Expenditure
1970	70.9	99.3	27.2	0.4	1.9	0.3
1971	67.6	99.3	29.8	0.4	2.6	0.3
1972	69.8	99.5	25.8	0.5	4.4	0.0
1973	72.2	99.6	24.6	0.3	3.2	0.1
...						
...						
1976	74.7	99.0	19.1	0.7	6.2	0.2
1977	72.6	99.0	18.2	0.5	9.2	0.5
1978	75.4	99.4	19.3	0.4	5.3	0.2
1979	73.8	99.5	21.6	0.0	4.6	0.2
			of which affiliated firms			
1979	7.2	77.5	1.6	0.0	0.2	0.1

Source: Horn (1981), cited in M. Ledic and A. Silberston, "The Technological Balance of Payments in Perspective", in Technology, Innovation and Economic Policy, P. Hall, ed. (Oxford, Philip Allan, 1986), p. 129.

Table 34. Number and percentage of contracts by manufacturing sectors, 1984

Country / Manufacturing sector	Argentina		Mexico 1/		Peru		Philippines		Portugal		Spain 2/		Egypt 3/	
	No.	%	No.	%	No.	%	No.	%	No.	%	No.	%	No.	%
Food, Beverages, Tobacco	20	6.5	61	21.1	25	26	14	22.2	8	5.8	29	5.3	0	0
Textil/Leather	32	10.3	28	9.7	7	7.2	1	1.6	23	16.7	34	6.2	2	14.3
Wood, wood products	0	0	0	0	0	0	0	0	0	0	0	0	0	0
Paper, paper products	5	1.6	15	5.2	1	1.1	3	4.8	4	2.9	9	1.5	1	7.1
Chemicals, chemical petroleum, coal, rubber plastic products	98	31.5	58	20.1	51	53.1	25	39.7	46	33.3	98	18.[illegible]	3	21.5
Minerals, non metallic	5	1.6	4	1.4	1	1.1	4	6.3	8	5.8	24	5.3	1	7.1
Basic metal industries	16	5.1	11	3.8	1	1.1	0	0	2	1.4	(incl. below)		1	7.1
Fabricated metal products, Machinery, equipment	130	41.8	98	33.9	9	9.3	16	25.4	42	30.4	309	57.6	6	42.9
Other manufacturing industries	5	1.6	14	4.8	1	1.1	0	0	5	3.7	32	5.9	0	0
Total	311	100	289	100	96	100	63	100	138	100	535	100	14	100

Source: UNIDO, Trends in Technology Transfer Flow, preliminary version, ID/WG.454/5 (Vienna, 1985), p. 35.

1/ New contracts only.
2/ The number of contracts include new, modified and extended contracts.
3/ Only transfer of technology contracts associated with foreign investment.

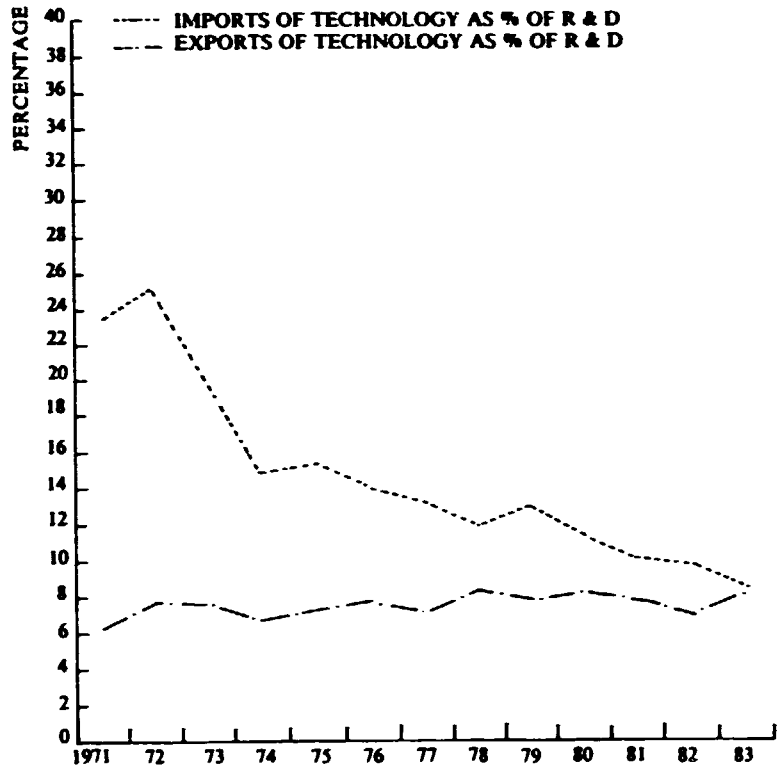
Table 35. Japanese education and immigration

	1955	1960	1965	1970	1975	1980	1982
Engineering bachelor's degrees awarded in Japan^a	9.6	16.6	30.0	48.7	65.0	72.6	73.6
Students studying in the U.S. a/	1.6	2.2	3.3	4.1	5.4	12.3	14.0
Japan's rank b/	4th	6th	5th	9th	8th	5th	5th
Immigration to the U.S. c/	7.6	4.2	2.7	1.8	1.5	1.7	
	2.8	1.5	2.3	4.7	7.6	8.4	

Source: L.S. Hiraoka, "Japan's Technology Trade", Technological Forecasting and Social Change, 28 (1985), p. 237.

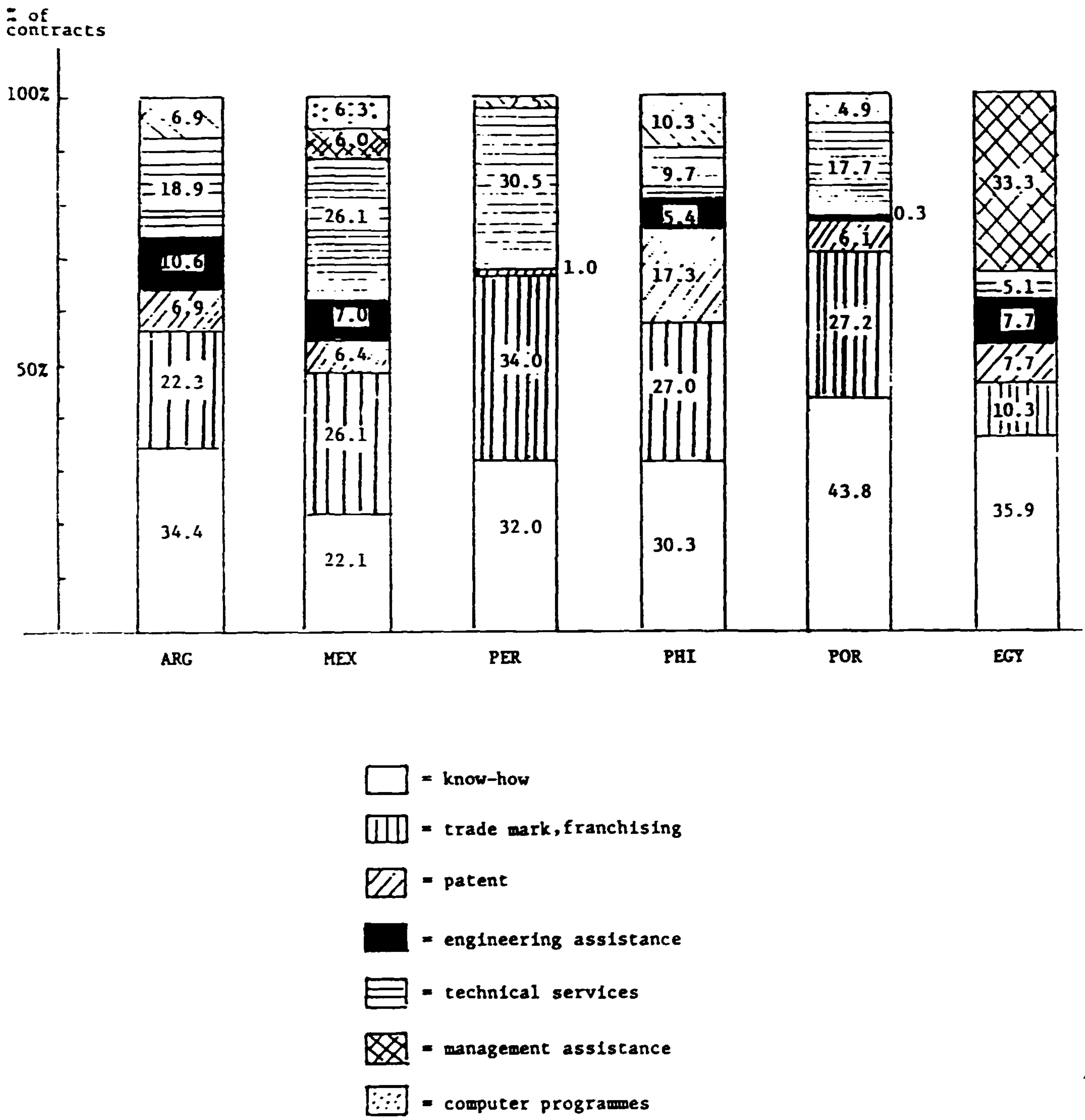
a/ In thousands.
b/ Rank among leading countries sending students to the United States.
c/ % professional, technical and kindred workers.

Figure XVIII. Technology trade of Japanese firms as percentage of their R&D



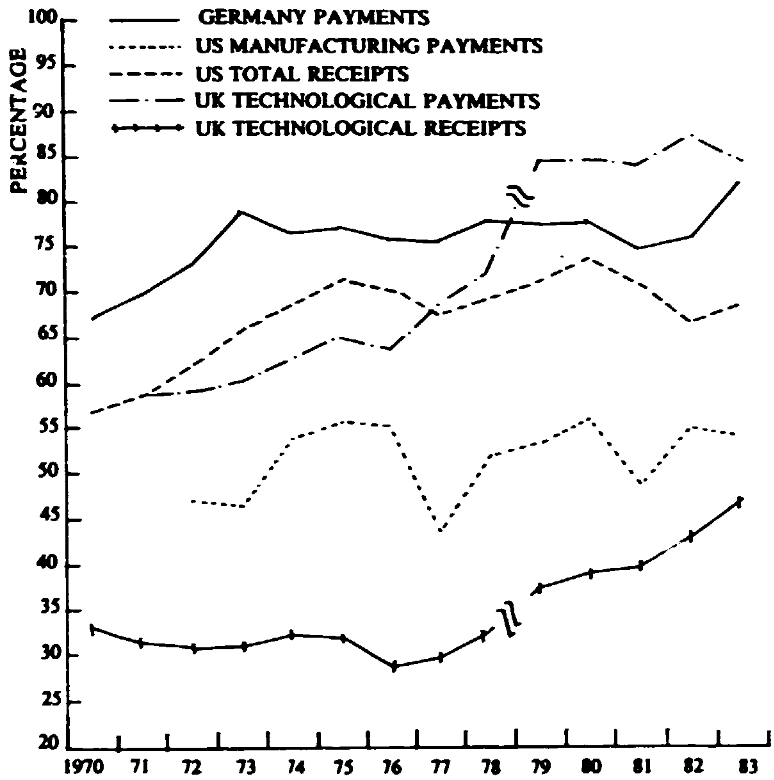
Source: G. Vickery, "Technology Transfer Revisited: Recent Trends and New Developments", Prometheus, vol. IV, no. 1 (June 1986), p. 31.

Figure XIX. Percentage of contracts by collaboration type, 1984



Source: UNIDO, Trends in Technology Transfer Flow, ID/WG.454/5, preliminary version (Vienna, November 1985), p. 33.

Figure XX. Associated firms' technology trade as percentage of total



Source: G. Vickery, "Technology Transfer Revisited: Recent Trends and New Developments", Prometheus, vol. IV, no. 1 (June 1986), p. 35.

VI. POLICY TRENDS

Several policy areas are relevant to the global trends that have been discussed in the preceding chapters. All fall broadly under industrial policy, or science and technology (S&T) policy; some areas are linked with, for example, education and fiscal policies. Many policy measures may not have been designed explicitly to affect the scientific establishment but nonetheless do influence it through indirect routes.

What happens far too often is that the important strategic issues dealing with the development of technological capabilities of firms, and consequently of industries, are caught at the boundary of two policy areas that usually are dealt with separately: industrial policy and S&T policy. Industrial policy tends to focus on the individual investment project rather than on national development; increasing total productive capacity is its overall objective. S&T policy often focuses on activities that are clearly identifiable as science and technology activities such as R&D; institutions outside the structure of industrial production are its main concern. This explains why questions and answers surrounding the accumulation of industrial technological capability have an unfortunate tendency to fall between industrial and S&T policy.

There is increasing agreement in this respect though perceptions of the emerging policy configurations vary. One argument is that industrial policy and technology policy are two sides of the same coin. Another observation is that industrial policy has lost its cutting edge, which has to be provided by technology policy. Another view provides a historical perspective. The 1950s and 1960s were marked in most OECD countries by "science policy" and "industrial policy" coexisting in a largely unco-ordinated manner. The recognition in the mid-70s that R&D is not synonymous with innovation resulted in increased coordination between the more traditional science and industrial policies and the introduction of new measures, such as "grants for innovations" as opposed to "R&D credits". The use of public procurement as a potential means to stimulate supplier innovations gained increasing attention. The 1980s are marked by "strategic innovation polices", involving the selection and support of generic technologies and high technology product grants through the establishment of major national collaborative programmes introducing inter-departmental initiatives. These programmes, which in the main focus on pre-competitive research, include the stimulation of inter-company and company-university research projects. They are aimed towards the structural transformation of industrial production towards high value added, and more knowlege-intensive sectors and product groups have a strong "reindustrialisation" flavour. (Rothwell, 1987)

Before proceeding to a discussion on some recent policy measures adopted by OECD countries, it is useful to set out a framework for classifying appropriate policy objectives and instruments (1). Policy instruments particularly relevant to the development of local (i.e., national) technological capability fall under one of the following categories:

	Category	Policy instruments
(a)	promotion of demand for local technology	. government purchasing . fiscal measures (taxation, price controls, export promotion, special credit, other financial incentives)
(b)	development of local scientific and technical infrastructure	. establishing institutions . planning/financing S&T activities
(c)	promotion of absorption of technology by local firms	. establishing credit lines . fiscal measures
(d)	regulation of technology imports	. controls on imports . foreign direct investment . patent system . licensing agreements . joint ventures
(e)	promotion of S&T-intensive enterprises	. establishing technical standards, . providing S&T information . providing training and access to consultants

Policy measures in OECD countries relating to technological advances have now been discussed in several publications (e.g., <u>Technovation</u>, vol. 5, no. 4, Elsevier, February 1987, and UNIDO IPCT.33, Technology Trends Series: no. 3, "Global Trends in Microelectronic Components and Computers", June 1987). Here only some salient features are highlighted.

Tax incentives have been used widely, particularly in industrialised, market economies. These are often preferred because they are seen to be the least interventionist. They have not always been very effective, however, especially when applied to the R&D end of the innovation process. Recently, tax incentives have been designed in such a way that downstream innovative activities (prototype building, for example) benefit.

Financial assistance incentives such as grants, risk-sharing investments and loan assistance have [illegible] been utilised, but little is known about their impact. One lesson learned is that bureaucratic procedures need to be simplified for the incentives to be fully exploited by firms.

Government procurement programmes have been used extensively to support private R&D efforts. Today they are being used more and more to support specific technological targets in clearly defined key industrial sectors such as information technology and biotechnology.

Japan's Ministry of International Trade and Industry plays an important role in the development of the country's industry. The influence of MITI, together with the [illegible] level of government and private industry co-operation, gives the appearance of a coherent industrial policy. It is argued that Japanese technology policy worked alongside market forces rather than replacing them with the political process.

A major strength of the Japanese system is its ability not only to devise long-term plans but also to implement them. The VLSI project, initiated in 1976, brought Japan to the leading edge of semiconductor technology by 1979. The project cost $250 million, with industry and government sharing costs equally. Over the course of the coming decade, several more MITI-sponsored projects are expected to yield dramatic results. For example:

(a) The fifth-generation computer is a 10-year project established jointly by MITI and eight major private firms. It aims to transform today's computer through the application of artificial intelligence and the utilisation of parallel processors. This initiative has forced many other countries to be more active lest they be left behind.

(b) The super-computer project is another long-term initiative seeking to develop a much faster computer for scientific and technical use.

(c) MITI has provided $100 million for a project to develop a new generation of robots. Both public and private research institutions are involved.

While Japanese firms co-operate during these pre-competitive stages of R&D, they compete with one another and with foreign firms by the time the ideas have reached the commercialisation stage.

Over the years, Japan has developed several mechanisms for acquiring technical information from all over the world. It has also acquired, successfully, technology through licenses and know-how agreements.

The U.S. Government sees itself as intervening as little as possible in the affairs of industry. It aims to foster an environment in which industry can survive and flourish. It will intervene whenever a company is monopolising power, but its general guiding principle is that the market is the best regulator.

This perception is, however, not strictly accurate in the high technology areas. Public purchasing activities of the space and military programmes are enormous and have wide-reaching effects on the scale and structure of industry. Between 1972 and 1982 the U.S. Government invested more than $280 million in IT-related R&D. Between 1980 and 1985 a military R&D programme concerned with very high speed integrated circuits spent $225 million. Major spin-off benefits are expected in non-military computer and telecommunications applications.

Western European governments tend to support industry through activities like R&D funding, promoting awareness and public purchasing. In 1984 EEC governments spent about $3.25 billion in support of IT industries. The amount directed towards pre-competitive research was merely one-tenth of the expenditure for product specific development. The biggest recipient sectors were components, opto-electronics, telecommunications, information processing, software engineering and computer-integrated manufacture.

European governments place a high priority on raising the awareness level on the role of information technology in improving the usefulness of the products and the competitiveness of production. A total of $300 million has been funnelled towards this end.

European countries use the purchasing power of their public sector, which is substantial, to support the development of their national industries. This is certainly the case for computers and telecommunications. Until the successful entry of AT&T into France, most European telecommunications markets had been regarded as virtually closed. Public purchasing can assist new firms to gain entry into the market and can enable established firms to develop new areas, but the danger is that the firms will become inefficient or uncompetitive at the international level.

The market of any single European country is not large enough to allow a firm to develop up to the scale and scope of its U.S. and Japanese competitors. The market provided by the EEC as a whole is sufficiently large, however. A co-ordinated use of these markets is one way of developing them into internationally competitive markets.

This prospect motivated the EEC to establish ESPRIT, a Community-wide programme that aims to provide support for pre-competitive research in advanced microelectronics, software, advanced information processing, office systems and computer-integrated manufacture. The programme will cost $1.5 billion over the next five years, shared equally by private industry and Government. The programme provides support for international collaboration between firms and research institutions in different member countries, complementing existing national programmes. Its ultimate objective is to provide European industry with a sound base for competing in the international trade of information technology. (Lalor, 1986, pp. 30-33)

Within Europe, though there is some agreement on the merits of being internationally competitive, opinion is diverging on the means to achieve this end. At first glance, France, the FRG, and the United Kingdom appear to have pursued very different policies. In 1981, the Socialist government in France nationalised all the major telecommunications equipment producers. The Conservative government in the United Kingdom recently privatised British

Telecom, opening the way for competition in the provision of networks and services. (Equipment producers have always been privately owned.) Government policy in the FRG has remained much the same despite a change in administration.

Despite the French and British differences over ownership, policies have recently converged similar to those adopted in the United States and Japan - for example, the trend towards state-supported R&D co-operation between telecommunications firms. In France, in addition to the ESPRIT programme, the telecommunications subsidiaries of Thomson and CGE have established a joint R&D laboratory. The Government is also subsidising, through its "programme filière électronique", joint R&D between both public and private institutions. The scheme has also been adopted in the FRG. In Britain, British Telecom has utilised the joint services of the three main telecommunications equipment manufacturers in the research, development and production of its "System X" telephone exchange.

The driving force behind these developments is the realisation that there is a discrepancy between the volume of resources required to develop new tehnologies and the size of European markets. Governments do not wish to support firms to re-invent the wheel.

Signs of policy convergence are also evident at the demand end - via the liberalisation of markets and trade. The reduction of trade barriers within Europe opens opportunities to firms for greater sales. Thus, investing heavily in new areas may become economic for them. Signs that this is happening are seen in the development of European standards for telecommunications and in the British Government's decision to allow British Telecom to order up to 10 per cent of its equipment from foreign suppliers. These moves towards trade liberalisation should not be interpreted as being totally technology-driven. The measures also reflect the increasingly dominant economic philosophy of Western governments. Success of this policy is not a foregone conclusion. Some firms may gain considerably; others, particularly small firms, may lose. Besides, trends towards increased co-operation, and possibly mergers, may be resisted by advocates of competition law. (Webber and Holmes, 1985, pp. 18-19)

Table 36 summarizes key policy measures considered or adopted by industrialised countries in biotechnology. Looking across national policies, eight common characteristics have been identified: substantial support for basic research; increasing emphasis on applied research; expansion of traditional policies for supporting R&D; a new emphasis on linkage between academic and industrial research; gradual convergence towards corporatist or quasi-corporatist policies; the popularity of the collaborative approach; the promotion of small firms and the venture capital market; and concern with the regulatory environment. (Sharp, 1987)

Developing countries

It is worth indicating in this chapter the policies adopted by some developing countries in information technology and biotechnology. The moves of historically rich and powerful countries to promote technological change pose a formidable challenge for developing countries. Some of the policies in the field of information technology adopted by Bangladesh, India, Pakistan, the Republic of Korea and Venezuela - countries at very different stages of industrial development - are presented here (2).

These countries have recognised the importance of acquiring and applying information technology for national development. However, only India and the Republic of Korea have drawn up strategies for the development of information technology. The Republic of Korea recognises information technology as a strategic industry, granting it the requisite status in the 1982-1986 five-year plan. India has also conferred special status on information technology in the development of national industrial and S&T policies. In its latest scheme to promote Export Processing Zones, Pakistan has given highest priority to the IT industry. Venezuela, however, has a glaring lack of a clear government policy in all industries except oil. Bangladesh is in the process of formulating a national policy in various technical fields.

As in industrialised countries, government's role in industrial development and the appropriate balance between the public and private sectors varies from country to country. In the Republic of Korea, government support is seen to be one primarily of creating an environment appropriate to the needs of private industry although the government does provide the framework for the educational system and the national R&D laboratories. In the more mixed economy of Pakistan, government's role is largely promotional with an emphasis on encouraging private investment.

Several countries have adopted liberal measures aimed at attracting foreign investment. Pakistan offers guarantees of capital and profit repatriation, a commitment not to nationalise industries, and tax exemptions or tax holidays. India and Pakistan have reduced duties on capital equipment imports and have restructured tariffs. The Indian and Venezuelan Governments have assumed a more active role by establishing state companies, regulating private companies and creating a protected market.

The nature of government R&D support reflects national priorities. In the Republic of Korea, industrial R&D is being carried out more and more within firms. Substantial industrial R&D is also being undertaken within national research laboratories, focusing on specific areas such as semiconductors, telecommunications and switching systems. National laboratories in India, which undertake much of the nation's R&D, are being encouraged to gear their work towards meeting specific industrial, scientific and social needs. In Pakistan, the recently established government institutes predominate in the IT area. For example, the Silicon Technology Development Centre, established in 1981 with U.N. assistance, will attempt to transfer the technology to local firms. The Centre will also engage in pre-competitive research on the development and use of silicon microchips. In Bangladesh, R&D is limited, with most of the activities being done within the confines of university departments and two national institutes. In Venezuela, governmental organisations conduct much of the research. A proposal to tax the productive sector to generate funds for local R&D activities is being considered.

Training and education are recognised as important basic needs and as largely the government's responsibility. Many routes are taken: introducing undergraduate and graduate programmes in new technology areas; sending students abroad for training; and making on-the-job training a condition of foreign investment in the country.

Countries have also followed various routes to acquire technology from abroad. The Republic of Korea has used most of the available mechanisms, with considerable success. India has been successful in encouraging foreign direct investment and in sponsoring overseas training of students. Joint venture arrangements have been less effective since imports of capital equipment are strictly controlled. Bangladesh has been involved mostly in assembly operations, which present limited opportunities for developing indigenous technological capabilities. These more traditional routes of acquiring foreign technology have not appeared to work well in Pakistan. Instead, the country has established Export Processing Zones as a way of gaining access to technological know-how. Venezuela has been able to develop an indigenous capability on the basis of local skilled manpower. For the last two decades, Venezuela has encouraged students to study abroad - an investment now beginning to earn returns. (Lalor, 1986, pp. 34-44)

The chief objective of the measures being carried out by Brazil is to develop a suitable scientific, technological and industrial infrastructure so as to enable the country to design, develop and produce strategic components in order to meet the needs of those national industrial segments whose evolution is dependent on microelectronics. Governmental initiatives include the setting up of the Microelectronics Institute of the Technological Centre for Informatics. The chief objective of the institute is to promote and co-operate in the development of microelectronics by encouraging and conducting R&D programmes along with universities, other R&D centres and industries.

Many countries will simply not be able to afford to enter into IT development. Capital equipment used in the production technologies of nearly all other industries is likely to contain some form of electronics. Countries that will have to import this equipment enabling them to reduce economies of scale and expand economies of scope would, at the very least, need the education and training to become informed buyers and to be able to maintain the equipment.

Several factors favour the development of software by developing nations: low wage scales and a large labour pool; the scarcity of adequately skilled software experts worldwide; the lack of software to meet local requirements; increasing software development, operating and maintenance costs in developed countries; and the proliferation of international subcontracting for software development. The prognosis for success is considered good though not entirely optimistic. (Schware, 1987, pp. 14-15)

Many problems associated with a new software industry must be addressed through policy and institutional reforms: shortage of labour with required skills; low capital availability; lack of management expertise; regulatory restrictions on the import of technology and software; language barriers; severe competition from large foreign companies; and difficulties in providing adqequate maintenance and follow-up support services. Table 37 shows the policies and strategies adopted by certain developing countries compared with those adopted by developed countries. (Mody, 1987, p. 23)

UNIDO's Technological Information Exchange System (TIES) has been collecting and exchanging information on technology transfer policies in addition to data on technology transfer flows. Some of the adopted legislation can be classified broadly as direct sales, licensing, technical assistance, management assistance and engineering assistance.

Many countries take into account the direct sale of computer programmes, models and industrial drawings, know-how and assignment of rights as technology transfer but do not say so explicitly. Only Egypt, Mexico and the Philippines mention these in relation to the assignment of industrial property rights, and only Brazil and Argentina in connection with computer programmes.

All countries require the licensing of industrial property rights and the licensing of know-how. However, some countries cover every industrial property right while others list only those they recognize, thus allowing them to exclude copyrights or trademarks. The legal status of computer programmes is not clear. They may be covered by copyright or are patented if embodied in particular hardware.

In regard to biotechnology, several developing countries have established national co-ordinating bodies and programmes for building up infrastructure and carrying out R&D. Such countries include Argentina, Brazil, Cuba, India, Kuwait, Mexico, Venezuela and Yugoslavia. In almost all cases, policy efforts for commercialisation do not appear to have been initiated.

Notes

(1) Techniques of policy evaluation are equally important but fall beyond the scope of this report.

(2) This section is drawn from a summary by Lalor (1986), based on country reports prepared for UNIDO by local experts in each country.

Table 36. Biotechnology policies in industrialised countries

A summary of recommendations made by experts on the development and promotion of biotechnology for their respective countries or community

Criteria	Recommendations/Steps taken: Countries/Organizations	Description
1. Definition of biotechnology	OECD	. To adopt a common definition of biotechnology.
2. Research and Development	CSIRO (Australia)	. Give highest priority for the continued development of techniques for genetic engineering in CSIRO. . Establish an industrial microbiology unit in CSIRO for innovative research with adequate research personnel . Continue research with recombinant DNA strains.
	OECD	. To support research, especially in plant genetics, microbial physiology and biochemical engineering. . To study new organisms other than Escherichia coli.
	Japan	. Classify biotechnology as one of the fields in which research and development should be emphasized. . Attention given to research which cannot be accommodated under existing research structures. . Government extending subsidies to universities, and private corporations pursuing research on biotechnology while itself also conducts its own research and development. . Government has set up a systematic programme for research and development of enzyme technology.
	France	. Government identified biotechnology as one of the major strategic areas for development on which the science law and funds will be focused. . French Government policy on R&D will give increased emphasis to high technology sectors including biotechnology.
	Chemical Economic Development Committee UK	. R&D in manufacturing industry should be increased on a selective basis. Biotechnology is one of the chemical sectors where the emphasis should be given.
	West Germany	. Government plays an active part in funding and planning biotechnology R&D in universities and industry.
	Allelix Inc. Canada	. Will spend $100 million over the next 10 years focusing on the development of biotechnology-based products and process for commercialization.

continued

Table 36. (continued)

Criteria	Recommendations/Steps taken: Countries/Organizations	Description
3. Manpower and Training	CSIRO (Australia)	. To consider the needs for increased manpower in industrial post-graduate training, including biochemistry, microbiology and chemical engineering. . To introduce industrial post-graduate awards financed by the Science Research Council to attract more participants.
	OECD	. To increase specific skills in the interdisciplinary context of biotechnology at university level and above.
	Second European Congress of Biotechnology	. To provide opportunities for organizations to advertise vacancies available so as to attract biotechnologists from countries whose government lack interest in biotechnology.
	Chemical Economic Development Committee UK	. Calls for an increased output of scientists with appropriate skills - biologists, biochemists, toxicologists and others.
	Royal Society, UK	. Call for a concerted drive by the British Government to develop an active national policy on education for biotechnology. . The research and teaching efforts in biotechnology should be based in a few centres which must be provided with sufficient staff and funds.
4. Co-operation between Universities and relevant Research Groups and Industries	CSIRO Australia	. To take positive steps to foster close cooperation and collaborative work between the molecular and other cellular biology units, universities and other relevant research groups in Australia. . To facilitate mutual exchange of competent staff between CSIRO, universities and industries by secondment or other practical means to accelerate research and commercialization targets.
	Japan	. Private corporation advancing research vigorously in new fields through technical licence agreement with their foreign counterparts with the aim of developing commercial processes.
	Britain	. Formation of biotechnology company whose objective is to make available for use by industry a range of products and know-how derived from outstanding biotechnology research in UK. . Establishment of specialized organic SWP to coordinate the efforts of interested parties to increase the total UK effort in this field and should be actively pursued.

continued

Table 36. (continued)

Criteria	Recommendations/Steps taken: Countries/Organizations	Description
5. Laws and Regulations	OECD	. To investigate possible legal and institutional solutions to the problems raised by industry-university links so that trade secrecy does not prevent the dissemination of information. . To investigate and compare the various patent systems of OECD countries with a view to making them more suitable for the new realities of biotechnology and possibly achieving harmonization between various countries. . To study the problems connected with the dangers and regulations governing the use of biotechnology especially at industrial level.
	Second European Congress of Biotechnology	. To review the regulatory policy on human therapeutic products, since the present regulatory requirements may be doing more harm than good.
6. International Trade and Markets for Biotechnological Products	CSIRO Australia	. To make every effort by CSIRO to secure relevant prompt information on existing and potential international markets for biotechnological products, and to seize the world market for Australian products.
	OECD	. To undertake a serious study of the long-term economic impact of biotechnology and to examine any ensuing changes in international trade. . To evaluate raw materials needs and costs and examine the competitiveness of biotechnology compared to other technologies.
	Chemical Economic Development Committee UK	. Companies in all sectors of the industry should be alive to the opportunities for exploiting development in biotechnology to serve worldwide markets.
	Canada	. Setting up of Allelix Inc. to develop a world scale biotechnology business.
7. Culture Collection	CSIRO Australia	. Conserve the existing major microbial culture collections in Australia and to accommodate future new strains in a National Microbiological Culture Collection Centre. . To facilitate national and international coordination of the component collections by supporting the World Data Centre.
	OECD	. To improve and fund microbial culture collections.

Source: extracted from Asia-Pacific Tech. Monitor (November-December 1984), cited in UNIDO, Genetic Engineering and Biotechnology Monitor, 1 (Vienna, March/April 1935), pp. 10-13.

Table 37. Measures to promote and protect software industries in selected developed and newly industrialising nations

	Mandatory Registration	Market Reserve	Procurement Preference	Government Subsidies	
				Domestic Firms	Foreign Suppliers
Developed nations:					
France	No	No	Yes	Yes	No
Japan	Proposed	No	Yes	Yes	No
United Kingdom	No	No	No	Yes	Yes
Newly Industrializing Countries:					
Brazil	Registration (Licensing Proposed)	Yes	Yes	Yes	No
India	No	Yes	Yes	Yes	Yes
Singapore	No	No	No	Yes	Yes
South Korea	No	Proposed	Proposed	Yes	No
Taiwan	No	No	No	Yes	Yes

Source: A Competitive Assessment of the United States Software Industry (Science and Electronics, Office of Computers and Business Equipment, Assistant Secretary for Trade Development, December 1984), p. 54; cited in A. Mody, Information Industries: The Changing Role of Newly Industrialising Countries (1987), p. 23.

Concluding Remarks

A variety of trends have been presented briefly in the preceding pages. All of them are concurrent and some of them are interrelated. What is the total picture that emerges and what are its implications? Different countries and firms may draw different conclusions in their own specific context. However, some observations are made starting with a quick summary of the results of previous chapters.

Chapter I has examined certain indicators of technological trends. Except for the smaller OECD member countries, R&D in general has been over 2 per cent of the GNP. While private expenditure of R&D has grown substantially, government funding for R&D has also emerged as a key factor in technology development; in countries such as France, the FRG, Sweden, the United Kingdom and the United States, it is well over 1 per cent of GNP. R&D expenditure has grown more rapidly than capital investment or domestic patenting except in the case of Japan. Co-operative R&D between countries has increased significantly through programmes like ESPRIT, EUREKA, etc. Cooperation in pre-competitive research has emerged as an important feature.

In some specific sectors R&D holds the key to growth. For example, in information technology as a whole, R&D expenditure of firms was generally about 10 per cent of the sales while for software it is as much as 35 to 55 per cent. Absolute figures apart, new types of R&D collaborations and management are emerging. University-industry collaboration has taken a new turn, while there is the growing phenomenon of science parks.

Altogether it may be said that there is a quantitative and qualitative intensification of R&D efforts, which in turn are the basic building blocks of innovation. New types of firm alignments particularly in relation to pre-competitive and generic technologies are readily entered into as strategic moves to keep abreast of galloping technological changes.

Judged in terms of patents, the technological strengths and weaknesses are spread over different regions. Japan is reported to be currently ahead in metals, electronics and automobiles, the United States in aerospace- and raw material-based technologies and Western Europe in chemicals, nuclear energy, conventional machines and production engineering.

Chapter II clearly brings out a trend which has not been highlighted by research elsewhere. The trend was indicated by the UNIDO Secretariat even at the time of the Tbilisi Forum in April 1983. (UNIDO, 1983, ID/WG.389/6) Subsequent events have only corroborated this trend, covering not only some but also practically all the emerging technologies. This trend relates to the realignments in the industrial and technology market structure. Industrial firms producing or having access to new technologies are more diversified than before. The consequence is not only for industrial production but also for acquisition of technology. The acquisition of technology in future may well be motivated not only by the specific technology that a joint venture can transfer, but also the kind of access to other technologies that the collaboration may provide. This has clear implications for developing countries.

In the case of information technology, particularly in semiconductors, telecommunications, computers and software there is a dynamic restructuring of the respective industries both within and among themselves. The reasons for such restructuring include those specific to each sector and also those general to all of them. The growing importance of personal computers may have relevance to the restructuring in the computer industry, while for simila reasons and in view of the close interrelationship between software and hardware, the restructuring of the software industry is also under way. In telecommunications the restructuring has mainly been triggered off by U.S. court decisions relating to AT&T and IBM. In the case of semiconductors the possibilities of vertical integration have been a major cause. But common to all the sectors is the fact that technologies have been converging and product segregation has given way to a product continuum. Products have often to derive their technological content from more than one of the sectors of industry referred to. In the case of user industries it has often happened that users have become producers of information technology, turning out applications software or creating new systems. In the field of software in particular the initial effort has been spearheaded by relatively small companies, which are increasingly being taken over by large companies.

The last trend referred to is a particular feature of genetic engineering and biotechnology. However, a trend towards transnational corporations is visible. For example, out of the 500 largest U.S.-based companies listed in Fortune, at least 83 have biotechnology-related activities. Among non-U.S. based firms, out of the 500 largest companies also listed in Fortune, at least 62 have biotechnology-related activities. Petrochemicals and chemical companies have been active in this field including in the acquisition of a large number of seed companies. A whole set of firms dealing with biotechnology equipment and chemicals for biotechnology R&D has also emerged.

In the case of solar photovoltaics, the structure of the industry has been considerably influenced by the dominant conversion technology of single-crystal, polycrystal or amorphous silicon cells. Petroleum firms have shown interest in acquiring companies specialising in solar cells in view of the relevance to energy markets, while semiconductor firms have an obvious relevance from the point of view of silicon wafers.

In the limited case of new materials that have been analysed, a similar trend in the industrial and technological market structure is seen. Firms moving into new ceramics include materials manufacturers diversfying into new materials; porcelain and glass industries that are upgrading themselves; and firms in processing and assembly industries that have identified uses for new materials. In the case of fibre optics, although it is dominated by a few companies, a considerable amount of vertical integration has been noticed between suppliers of fibres, cables and other components.

The position is no different in the case of manufacturers of flexible manufacturing systems and robots. These include robot users, machine tool manufacturers, software and engineering and construction firms, electric and electronic manufacturers, and computer manufacturers.

The alignments noted in all the above cases have several implications. They not only indicate the alertness and resilience of firms in diversifying in an era of changing technology and emerging market possibilities but they are also a testimony to the pervasiveness of the new technologies straddling across several industrial sectors. Figure XV in chapter IV is but one example of networks emerging between industrial sectors related either by the nature of the technology or its use. This has implications for corporate finance, corporate management and also for technology acquisition.

A separate chapter has been devoted to the use of new materials since the pervasiveness of such materials has to be fully understood. References are often made to the de-materialisation of industry and technology but on the other hand (and not necessarily in a contradictory sense), to the emergence of a new type of materials industry. Collection and analysis of information in this field is rendered difficult not only because of the wide range of materials but also because the uses of each material are spread over many industrial sectors and organised collection of information does not yet appear to have taken place.

Together with new materials, the changing concepts of industrial organisation and production discussed in chapter IV might well augur a paradigm shift in industry. The question is whether a new industrial culture is emerging where in addition to changes in its external links such as mergers and acquisitions, collaboration and funding of research and co-operation in pre-competitive research, the internal structure of a factory is also beginning to change with new concepts of design, production, marketing, inventory control, etc. Current evidence is sufficient to bring out this changing trend but it also discourages hyperbolic expectations. What is clear is that techniques of industrial organisation in general are likely to be as important as any specific technology in the narrower sense of the term. Such changes require considerable investments and also call for special managerial perceptions and corporate strategies.

Though technology transfer has been a major feature in international economic relations, whether between developed countries or between developed and developing ones, a global view of the trends and dimensions has been difficult to obtain particularly because of the difficulties in building and collecting national statistics. However, the need for a global view of the trends is evident especially in the context of the impact of the new technologies. Chapter V addresses the question of technology flows, in particular the trends in foreign investment and licensing. For example, the United States has emerged as a major recipient of foreign investment. The investment in developing countries is only about 25 per cent of total direct foreign investment and while in some countries a relatively liberal policy has increased the flow of investment, in others foreign investment is generally going through a period of rationalisation and restructuring. In the long-term the manufacturing sector is expected to attract direct investment, though currently service-oriented industries appear to be the most dynamic recipient sectors.

In many countries the share of high technology in technological balance of payments is increasing. Technology trade between independent firms is predominantly in traditional industries or industries with many small firms. Payments for patents, licensing and know-how have increased. In real terms they still contribute only 5 to 10 per cent of production from foreign direct investment. This relatively low share does not, by any means, underemphasise the importance of the flow of technology it connotes. Based on the information available in the Technological Information Exchange System (TIES), it has also been possible to provide information about at least some of the developing countries in relation to their technology trade.

Chapter VI has dealt with the policy responses of the OECD countries. Clearly the policy responses have involved a close interrelation between industrial policies and technology policies. Encouragement of R&D has given way to encouragement of innovation. Government funding of research has considerably increased, particularly to increase the overall technological capability in generic technologies and to prepare the ground for future technological breakthroughs. A variety of policy instruments have been considered both for information technology and biotechnology, with the governments being concerned with the competitive position of their respective countries in the future. Several common characteristics of national policies have been identified. However, in the case of developing countries the emphasis seems to be primarily on capability building which by itself is to be fully commended. However, attention to interaction of capability building with the commercialisation into production does not seem to have been given.

The degree of diffusion of technological advances depends not only on the degree of maturation but also on the nature of the technology and the market opportunities. Sometimes diffusion is considered automatic but this is not the case. In this connection, it is most important to consider the agents of technological change and application. These would be enterprises, government departments and a wide range of professionals such as agricultural extension workers, public health personnel, etc. It is through them that the actual diffusion of technological advances will take place. The induction of new technologies will be governed primarily by economic considerations combined with a number of technological and social factors involving, _inter alia_, acceptance of new products and technologies by producers and users. For example, the enterprises that consider the introduction of new technologies will be concerned with the investment requirements, the replacement of existing usable equipment and considerations of cost, competitiveness and technical advantage. Similar considerations will be applied by users. For them the new technologies should result in products that are better than existing ones in terms of effectiveness and cost and can fit into the general milieu in which their use takes place.

The difficulties associated with the introduction of microelectronics in industries in France, the FRG and the United Kingdom have been identified by the firms surveyed as lack of expertise, economic situation, development costs and difficulty in obtaining development finance, technical problems in software, etc. In biotechnology the difficulties in commercialisation of research results are not so much in terms of finance but are essentially problems in scaling-up. In the case of new materials the speed of application is governed by the conflict or identity of interest between the manufacturer of new materials and the user. In the case of the automobile industry, for example, cost considerations, quantity ordered, exclusivity of the material and the product, tendencies to diversify in each other's territories, etc. govern the extent of use of new materials.

In general, the economic environment, the social and educational context, and government and management support will be factors governing the pace of introduction. Within the framework of such general considerations, the factors relevant to each technological advance have to be considered in depth. For example, replacement of existing equipment, often an important consideration, will not arise when new industries are set up. For biotechnology processes, existing fermentation equipment may not be redundant. Several of the new technologies would require adaptation to local conditions. Country-specific microelectronics applications and biotechnology in general require a high degree of local adaptation and close interaction with the users.

The trends discussed in this report and in particular the changing industrial and technological market structure, the new facets of university-industry collaboration, the new elements in transfer of technology and R&D relating to enterprises and the emerging product continuum in information technology, have obvious implications for enterprises and managers. Managers in general will be increasingly called upon to display several traits, some of which will require reorientation of attitudes and departure from company traditions: decision-making in a wider range of uncertainty, understanding of implications of new technologies and the perspective of a changing industrial scene, resilience and flexibility, interdisciplinary team work and a new attitude towards competition and co-operation.

A workshop organised by UNIDO on the institutional and structural responses of developing countries to technological advances (UNIDO, 1983, ID.WG.401/7, p. 28) concluded that at the level of the firm, the technological advances call for:

(a) a minimum of in-house R&D capability to be established in the larger industrial units;

(b) internal reorganisation in interdisciplinary task forces charged with specific development or production targets;

(c) stricter quality control and higher levels of workmanship and emphasis on full and detailed documentation;

(d) good, flexible and responsive information systems within the firm and with the outside;

(e) emphasis by management on the encouragement and easy flow of innovative ideas;

(f) interest in, support to, and financial participation in the exploitation of useful applications developed in academic or R&D circles; and,

(g) encouraging firms to formulate and implement long-term corporate strategies and plans for exploiting the technology advances, based on current and expected states and directions of development of these technologies.

It should be stressed that the management of technological change in general is not a matter solely confined to firms and their managers. While they continue to be the primary agents of technological change, policy-makers in government departments have an important role to play, as evidenced by the increasing role of governments in fostering the growth and application of new technologies.

It is clear that enterprises and governments should closely follow technological developments and use the information to review and modify firm strategies and government policies. Since the situation is highly dynamic, the subject requires attention and action on a continuous basis. To help in this process, the UNIDO Secretariat intends to continue its monitoring activity on the lines explained in the introduction.

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