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THE CHANGING TECHNOLOGICAL SCENE: TRENDS IN SELECTED DEVELOPING COUNTRIES

Prepared by

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CONTENTS

INTRODUCTION

This study is a synthesis of a series of analytical papers and studies undertaken by UNIDO on trends in new technologies particularly in electronics and informatics, biotechnology and advanced new materials, and technology policies and flows of technology in developing countries in recent years. The study reviews the major implications of new technologies in these fields for developing countries, together with trends in the inflow of industrial technology into these countries, and examines the changes in national policies towards foreign technology and their likely impact in the immediate future. The major technological developments in microelectronics, biotechnology and in advanced new materials are discussed, together with implications and experience of such developments in these countries. With the enormous variation in socio-economic conditions and levels of development, it is only practicable to relate the pattern of technology flows and trends in new technological applications to the experience of selected countries in different regions and at varying stages of economic and technological development.

The pace of technological development has accelerated rapidly in the last two decades and several technological innovations are having significant impact on various production and service sectors. These developments are most reflected in a variety of new technological applications based on microelectronics which, combined with innovative developments in biotechnology and advanced new materials, are having a revolutionary impact on products and processes in most fields. A new era of information processing or informatics has developed. Technological developments in fields such as lasers and remote sensing continue to evolve in a multi-dimensional pattern of technical innovations. These developments have taken place primarily in industrialized, developed economies, but their pervasive nature and impact will inevitably have major repercussions on all economies, including those of developing countries.

New technologies incorporate major technological changes brought about by innovations in new processes, products and services. These technologies and their resultant products are usually both knowledge-intensive and research-intensive and are generally inter-disciplinary and intersectoral in their applications. These technological developments are also marked by continuing changes and a high rate of obsolescence, often because of successive and rapid incremental innovations, which are capable of extensive diffusion and application in different sectors.

The impact of new technologies extends from major changes in industrial processes and operations and use of new ranges of equipment, combined with organizational changes, on the one hand, to the substitution by new materials of several minerals and products exported by developing countries and changes in competitive production capability on the other. As a result of developments in microelectronics and automation, the major factor advantage of cheap labour in most developing countries has become greatly eroded. Microelectronic technologies are expected to have significant effects on employment and labour in developing countries and on socio-economic and environmental conditions. Developments in biotechnology are also likely to have considerable impact on production sectors such as chemicals and pharmaceuticals and over a wide range of agro-processing and food industries, which would be of vital interest for developing countries. These technological developments can be effectively harnessed for socio-economic progress and can be extensively utilized for economic and industrial development and in achieving increased productivity and efficiency.

It is important to stress that, while the study deals primarily with three major categories of new technologies, namely, microelectronics, biotechnology and advanced new materials, several other categories of new and emerging technologies are closely interlinked. The development of new, renewable energy technologies, ranging from increasing use of biomass and geothermal energy to the development of photovoltaic cells and processes harnessing solar energy, would also undoubtedly be of great importance and significance for developing countries. These developments constitute an integral element in the process of overall technological innovations and change, which are not only closely inter-related and converging with one another, but extend to several new technological frontiers in photonics, opto-technology, biomimetics and other fields characterized as high technologies. With respect to industrial growth patterns, however, the most immediate impact will be of microelectronics and new materials, together with biotechnology and genetic engineering and it is consequently on these areas that this study concentrates.

There is considerable awareness and knowledge of global technological trends in most developing countries and this is reflected by changes in policies towards inflow of industrial technology in several of these countries. So far, however, the nature and extent of technology flows to these countries has not extended significantly to microelectronics technology or with respect to biotechnology and new materials. The trends, potential and implications in this regard have been highlighted in this study. The limited transfer of technology in these fields may be a cause of considerable concern as this would further extend the technological gap between industrialized and developing countries. It may be necessary to review policies and institutional arrangements in these countries with respect to investment and technology inflow and to develop appropriate means and mechanisms through which new technologies can be acquired, utilized and adapted to the requirements of developing countries.

The study is divided into nine chapters. The first chapter provides an overview of trends and impact of new technologies, particularly on industrial growth and competitive capability and examines developments in certain specific fields impacting on industrial growth, namely, integrated manufacture; technological change in the machine-tool industry, and technological developments in telecommunications, besides the implications of new technologies, particularly electronics and informatics, on employment and industrial development. The second chapter deals with technology flows to developing countries in recent years, together with changes in technology policies, particularly those relating to foreign technology, in several of these countries. The third chapter describes the nature and extent of foreign technology inflow, as well as national technology policies in selected developing countries. The fourth chapter deals with trends and developments in microelectronics and informatics, while the fifth chapter describes the experience of selected developing countries in these fields. Chapter VI deals with developments in biotechnology and Chapter VII covers the experience of selected developing countries in this regard. Chapter VIII deals with technological developments in advanced new materials and implications for these countries, together with trends and prospects in developing countries. Chapter IX discusses the policy implications and institutional arrangements which may need to be considered by developing countries to deal effectiely with new and emerging technological developments.

This study was prepared by Rana K.D.N. Singh, of International Industrial and Licensing Consultants, Inc., and draws extensively on several reports, studies and papers prepared for UNIDO.

CHAPTER I

NEW TECHNOLOGIES AND COMPETITIVE CAPABILITY

Recent technological developments in microelectronics and informatics, together with biotechnology and advanced new materials are having far-reaching impact on industrial growth and various sectors of production and services and are bringing about significant changes in products and in production processes and techniques. The structure of entrepreneurship and of industrial organization and management is also undergoing considerable transformation in most industrialized economies. The most significant impact, however, has been on production processes and operations, and on organizational patterns, most of which are still in the process of evolution and change. In the industrial sector, innovative developments in machine tools and in integrated manufacture are having major impact on production processes, with greater emphasis on research-based technological applications, which are marked by continuing evolution and changes. There is also a high rate of obsolescence, often because of rapid incremental innovations, which are capable of diffusion and use in various sectors.

New technologies extend to most sectors and an enormous range of applications. There are, however, three principal categories of such technologies where major and revolutionary technological developments are taking place, which would have considerable repercussions on industrial growth. These are microelectronics and informatics, biotechnology and genetic engineering, and advanced new materials. These fields are closely interrelated and a combination of developments in these fields is having major impact on various sectors and applications, such as remote sensing; aerospace engineering; space and marine technologies, lasers, optic fibres, bio-enginering and bio-electronics and other such fields. Technological applications in these areas differ considerably in their respective stages of development. The most rapid developments in recent years have been in the field of microelectronics and informatics and innovations in data processing and communications are having substantial effect in various production and service sectors. Developments in biotechnology and genetic engineering are at a slower pace but would have very extensive ramifications in production sectors such as pharmaceuticals, chemicals and food industries, besides various agro-processing operations, livestock development, and a wide range of industrial applications. With respect to advanced new materials, several technological developments have reached the level of application and usage, both in fields such as aerospace engineering, satellite communications and the like and in production of capital goods, including automobiles and transport equipment and a growing range of high-technology industries.

While rapid technological innovations are taking place in the three fields of electronics and informatics, biotechnology, and new materials and there is growing convergence in technological developments in these and other new technologies, there are likely to be considerable differences in their effect, in terms of the sectors of application and the extent of impact in the next 4 to 5 years. Developments in biotechnology are increasing rapidly, particularly in pharmaceuticals and health sectors and in various agricultural applications, and their effects are likely to be more far-reaching over a longer period, except in agriculture. Developments in new materials and synthetic products would have considerable impact, depending on the materials to be substituted. The effects of replacement of copper cables by optic fibres or of sugar by aspertame and artificial sweeteners would be fairly gradual though of major long-term significance, while advanced new materials such as polymers, composites and ceramics would continue to be utilized for some time mainly in certain high-technology sectors such as aerospace or satellite engineering and development. Developments in electronics and informatics, however, are already being extensively applied in several sectors of industrial production and their impact on competitive capability is likely to be very significant in the immediate future. From the viewpoint of industrial competitiveness, electronics technologies must be considered to be of special significance, including over the short-term period.

Impact on developing countries

The implications, experience and potential of new technologies, especially microelectronics, new materials and biotechnology, in developing countries varies considerably. There is a wide range of diversity between the export-oriented economies of several South-East Asian countries, where microelectronic products and processes have been absorbed and adapted, to a large number of less-industrialized developing countries, relying largely on exports of minerals and materials and where new technological applications have been very limited. The effects on developing countries are likely to be both negative and positive. 1/ The negative effects are likely to be on exports of minerals, commodities and traditional processed products from these countries because of substitution by new materials, and, even more importantly, on international competitive capability in production and manufacture in several fields. On the positive side, developments in microelectronics, biotechnology and in advanced new materials can provide major opportunities and potential for a number of developing countries, provided production processes can be suitably adjusted and adapted to such technologies.

There will be significant impact of advanced new materials on developing countries by way of replacement of existing minerals and other materials presently exported by developing countries. New synthetic materials are likely to bring about considerable substitution of minerals, such as copper and iron ore and of processed products such as sugar. In the case of the latter, there has been considerable substitution of sugar by sweeteners such as starch-based high-fructose corn syrup (HFCS) and cyclamates and aspertame. Certain studies estimate that HFCS and non-caloric sweeteners, such as aspertame, may reduce the demand for sugar in food industries by up to 70 per cent. 2/ The substitution of minerals by new materials, polymers and composites, is likely to substantially reduce mineral exports from developing countries. The replacement of copper by optical fibres for telecommunication cables is bound to have considerable effect on copper-producing countries such as Chile, Zaire and Zambia.

The use of steel in automobiles and transport equipment has been reduced considerably because of less use of specialty steels and increased use of composites and new materials. Similar reduced usage is also likely to take place in capital-goods production, as also in engineering, processing and construction industries. Other commodity exports from developing countries may also be similarly affected. Products such as cotton, natural rubber, sisal, roundwood, pyrethrum, etc. are facing reduced global demand because of substitution and reduction in the intensity of material use. This trend is likely to get increasingly accentuated and there must be adequate awareness of such developments well in time, so that exporting countries can undertake suitable alternative programmes.

Competitive industrial capability

New electronics and imformatics technologies are likely to have the most impact on international competitive capability in industrial production. The extent of such impact would depend on the production sub-sector and the effects of new technological processes in that field. Technological changes have largely taken the form of computer-aided design and manufacture (CAD/CAM), flexible manufacturing systems (FMS) and increased use of automation and robotics in several fields. These developments have brought about significant changes in comparative advantage, particularly in the reduced factor advantage of labour. The application of CAD/CAM and FMS has also introduced much greater precision and dynamism in design and engineering and in production processes in most fields of manufacture. The impact of these developments needs to be viewed specifically in three critical fields, namely, (a) integrated manufacture, (b) changes in machine tool applications, and (c) developments in information and telecommunications.

(a) Integrated manufacture: Increasing competitive pressure in manufacture is now combined with the powerful range of new technologies based on automation which have become available during the 1970s and 1980s. 3/ The increasing use of computer-based systems for co-ordination greatly facilitates production management activities such as planning, scheduling and programming of production. The functional areas of manufacture, such as design or quality control are being brought closer to manufacturing, while the overall co-ordination process for production is increasingly being linked to other business functions through computer-integrated manufacturing (CIM) in which all the functions of a manufacturing business are not only automated, but also integrated with each other via a range of networks and communications software. This includes: (a) design and pre-production, which includes all the tasks necessary to identify and prepare products for manufacture, (b) production, where the information is translated via a series of operations into physical form, and (c) co-ordination, extending to various managerial tasks needed to support the manufacture of the product from initial design activity to sales and distribution.

As demand for increased production flexibility increases, the potential applications of such integrated automation would also become increasingly extended. This represents a major change from earlier generations of automation which were confined to larger scale and high-volume industries. In the latter fields, the pressure has been mainly to increase production and productivity as cheaply as possible, while maintaining quality standards. However, this pattern is changing and the pressures now are for greater flexibility and agility, even in commodity-type businesses. Increasing use is being made of programmable controls, robotics and flexible manufacturing sytems; CAD/CAM; and other technologies. At the same time, organizational changes are leading to smaller workforces and plants producing with greater flexibility and quality through the application of alternative management approaches such as just-in-time (JIT) manufacture and total quality control (TQC). These changes are most evident in the engineering industry. However, in other fields, such as semiconductor production, the pressure has been growing for high quality, rapid product changes and increased variety to suit user-specific needs. This has led to growing integration in the manuacturing process. In the case of small batch manufacture, such as in capital goods production, the opportunities opened up by CIM are very substantial. With much of engineering production taking place in batches of less than 50 items, integrated automation technologies such as CIM and FMS, which offer both productivity and flexibility, provide considerable competitive advantage. There are several examples of CIM across a wide spectrum of industries. However, the high diversity involved in "batch" production in engineering-goods sectors represents a major advantage and opportunity for application of advanced manufacturing technology.

There are, however, several factors which can militate against integrated manufacturing operations. These factors, which would be greatly accentuated in most developing countries, include (a) investment costs, (b) technological problems, (c) lack of in-house skills and resources, and (d) organizational factors. Investment costs of integrated manufacturing technology are high and may generally extend from over $1 million to several million dollars. The basis on which investment is justified, however, and techniques in this regard are undergoing changes. Simple return on investment techniques are being replaced by complex alternatives that take account of the strategic issues and try to provide a quantitative rationale. The technical problems relate mainly to the difficulties of integrating different elements. Physical integration of equipment is relatively straightforward, but software integration can be a major constraint. Lack of in-house skills and resources constitute an obvious shortcoming, which would be all the more applicable in developing countries. Organizational factors must also be taken into account.

A number of important organizational and managerial innovations are increasingly linked with integrated production facilities, many of which have been developed in Japan. The most important of these techniques is just-in-time (JIT), which has now been adapted and is being used in a wide variety of sectors and countries. In its simplest form, JIT allows for minimal batch sizes and inventories. Components are not held in stock but delivered by suppliers to the point where they are needed just-in-time to be used. The direct benefits are clearly in the area of inventory savings, which are of growing improtance because of increasing materials costs. JIT techniques enable (a) reduction of set-up time, particularly for multi-product operations; (b) use of multi-function workers, with high degree of skills and flexibility; (c) uniform output rates, achieved by standardization in various elements of the manufacturing process.

Apart from JIT, the concept of total quality control or "zero defects manufacturing" is another system that has been successful in Japan and is now being applied widely in other industrialized countries. Its overall aim is to entrust responsibility for quality to the shop-floor and make it a direct part of the process rather than an indirect activity. The aim is to guarantee zero defects in production, hence providing maximum quality assurance to customers.

Another important approach towards greater flexibility in manufacturing is group technology. This groups products into families and process equipment for making a family in the same place, rather than the traditional flow-line concept which groups different types of process technology together. Such approaches are appropriate for small-batch, high-variety work and also assist in reducing layout complexity. An extension of the group technology concept is the idea of "mini-factories" within a larger plant. In such a facility, all the necessary inputs to production for a particular family of products, including functional support services, are grouped together.

The development of a strategy for computer-integrated manufacture can take alternative routes. One approach involves installing islands of automation based on advanced technology, gradually working towards linking these into a fully integrated factory. The alternative approach is to introduce organizational and management changes first. This implies an incremental approach based on low-risk, high-return organizational changes building up gradually to higher-risk technological changes such as CAD/CAM and CIM. Manufacturing competitiveness in future years is likely to depend considerably on the ability of firms to exploit computer integration in manufacturing technology and techniques within an integrated organization.

Computer-integrated manufacturing technology offers a powerful weapon for tackling various problems facing manufacturers. Enterprises in developing countries have to overcome significant difficulties in moving away from discrete applications of programmable automation and towards integrated solutions. These will involve problems of high cost, lack of skills, lack of suitable technology and a supply market that is still maturing. Obviously, production enterprises with limited resources and experience should initially concentrate at the technological level on well-proven programmable automation applications, such as numerically-controlled machinery, low-cost CAD, low-cost production management aids and basic microprocessor controls for process operations and use these to enhance flexibility, quality and productivity. Wherever possible, however, there should be a gradual shift to integrated manufaucturing operations.

(b) Changes in machine tool applications: An important aspect of introducing CAD/CAM and CIM techniques arises from the major changes that have taken place and are occurring in machine tool technology. 4/ The most important technological development in the engineering industry has been the fusion between mechanical and electronics technology, known as "mechatronics". This affects not only machine tools, but also the capability to integrate machine tools with other machinery. Numerically-controlled machine tools (NCMTs) have become standard machine tools for a range of primarily metal-cutting functions such as turning (lathes), milling, drilling and boring.

The two most important NCMTs are CNC (computer numerically-controlled) lathes and machining centres. These two types of machines account for over 60 per cent of the value of production of NCMTs in the leading OECD countries. Computer numerically controlled lathes increased from 23 per centof the total output of lathes in 1975 to nearly 80 per cent in 1986. The same trend applies to machining centres as substitutes for conventional milling machines. While in 1976, machining centres accounted for only 38 per cent of the production of machines performing milling functions, the share rose to 65 per cent in 1986 (Table I.1).

While rapid increase in NCMTs has been the main feature of the diffusion of new technology in the engineering sector since the mid-1970s, it is the diffusion of NCMTs incorporated into systems which will dominate the future. These are flexible manufacturing modules (FMMs) and flexible manufacturing cells (FMCs), comprised of several machine tools (2-5) linked by an automatic material-handling unit and controlled by a common information system. In addition, there are also larger systems, commonly called flexible manufacturing systems (FMS) which consist of several FMCs or a larger number of machine tools, with automatic material-handling facilities and a common information system.

Numerically-controlled machine tools are increasingly utilized in both the industrialized, developed economies and in the newly industrializing countries (NICs). In Table I.2, the estimated stock (column 1) of NCMTs is given for some newly-industrializing countries, and some developed countries. Among the newly-industrializing countries, the Republic of Korea is the largst single user of NCMTs, with a stock of 2,680 units in 1985, followed by Brazil and India. Among the developed countries, Japan is the largest user with 118,000 units installed by 1984. In terms of density (column 2) in the use of NCMTs, the newly industrializing countries are still far behind developed countries. The leading developing country in terms of using NCMTs, the Republic of Korea, had a density of only about half the value for the United Kingdom. Taken jointly, the five newly industrializing countries (excluding Argentina) had an average density of 1,665. The developed countries had an average density of 14,230 which is 8.5 times higher.

The largest producers of machine tools are by far Japan, Federal Republic of Germany, Soviet Union, United States and Italy. Jointly, they accounted for more than 70 per cent of the global production of machine tools in 1985. Among developing countries, China ranks highest as number 10, while Taiwan Province is number 13, Brazil number 14 and the Republic of Korea and India follow with number 18 and 20, respectively. Jointly, the developing countries accounted for not more than 6 per cent of the output of all countries. In 1972, developing countries accounted for only 2.6 per cent (UNIDO, 1975). The industry is, on the whole, fairly internationalized as far as trade is concerned. In 1985, 44 per cent of output was exported. Smaller countries generally have a higher export ratio than most of the larger countries. With the exception of Taiwan Province, the developing countries have low export ratios, largely because of growing internal demand.

The impact of new machine-tool technology on shop-floor productivity is not only a function of the new machine tools being introduced, but the ability to organize the proper interaction of labour, machinery and materials. Both group technology and JIT have been applied to conventional machine tools also, but their use is generally associated with the adoption of NCMTs. It is evident that the advent of micro-electronics, both in the machine tools and in the modes of communications, has led to considerable widening in the scope of application of these organizational forms.

The use of NCMTs has become an industrial standard in some fields, either because of high precision requirements in certain product groups or the need to ensure flexibility in meeting varying product specifications within relatively small batch production. Where this is the case, there is no alternative for developing-country enterprises also to introduce NCMTs in production. The present level and rate of diffusion of NCMTs is substantially lower in newly-industrialized developing countries than in developed countries. There is lack of information about NCMTs and a lack of knowledge of how to use, repair and maintain such aquipment. In addition, the price of NCMTs is very high in relation to both the price of labour and the price of conventional machine tools. This reduces the scope for profitable application of NCMTs. The high local prices of NCMTs are to some extent, due to industrial policies which foster local production of machine tools. This has led to a higher self-sufficiency ratio in terms of NCMTs in, for example, Argentina, Brazil and the Republic of Korea, than in the United States and in the United Kingdom. This high self-sufficiency ratio can, however, lead not only to high unit costs, but also to a lack of choice for local customers. It is difficult for any local industry to supply national markets with all types of NCMTs.

Industrial policy in developing countries could aim at removing obstacles to faster diffusion. As far as information is concerned, a number of developing countries, such as India, the Republic of Korea and Taiwan Province, have set up national institutes which have the function to diffuse information about new technology. As for knowledge and skills, this relates to the functioning of the educational system. Greater emphasis should be given to educating operators of NCMTs and to the associated programming, setting and maintenance staff. While the present diffusion of NCMTs in developing countries is far from optimal, this may be largely due to greater availability of conventional machine tools. In the Republic of Korea and Taiwan Province, only 20 per cent of the production of machine tools was in the form of NCMTs in 1986. Large production capacity in conventional machine tools also exists in China, India and Brazil. Accordingly, access to conventional machine tools will probably not be a problem, in these countries, even in the long term and the issue is that of timing and extent of shift to NCMTs in the next few years.

There is considerable production of NCMTs in some more advanced developing countries, including China. The largest producers are Taiwan Province with a production of 1,917 units in 1986; the Republic of Korea with 1,124 units and Brazil with a production of 710 units in 1986. India produced 193 units in 1987. To the extent that development strategy aims at integration with the world economy, government policy for the machine tool sector should aim at fostering internationally competitive firms which eventually develop as full-scale participants. At the same time, the instruments of intervention should be chosen so as not to reduce the scope for choice for the local metalworking industry as regards different variants of machine tools. Imported technology may be required to ensure that the local metalworking industry keeps up to date in production technology. The pressure to rely on imported technology, be it embodied in products or through licensing agreements would, of course, tend to be greater the smaller the size of the local machine tool industry. To the extent that import of embodied technology is prohibited, it is necessary to ensure adequate diversity of choice for the local engineering industry, necessitating multiple foreign technology supply arrangements. The experience of India in regard to machining centres might be illustrative here. Till the end-1970s, there was only one producer of machining centres offering only a limited range of models. In the early 1980s, consequent on considerable liberalization of industrial policy, eight Indian manufacturers obtained licensing agreements with international producers of machining centres. As a result, the diffusion of machining centres has now increased significantly.

(c) Information and telecommunications: Apart from the development of competitive production capability, an area where developing countries may face a growing technological gap unless remedial measures are taken, is with respect to information processing and communications. The revolutionary developments in telecommunications and data processing, storage and dissemination, have ushered in a new era of informatics, comprising an integration of communications, data processing and information technologies. These developments also necessitate a review of national strategy as to the stage and level of development which particular countries should seek to achieve within a reasonable period. The digitalization trend of public information transmission networks and the integration of services have led to the development of specialized equipment for the establishment of networks and the proliferation of terminals. The increased usage and local production of such equipment has considerable potential in many developing countries, apart from the need for keeping pace with developments in communication technologies for access to international data bases and information systems and networks. The communications sector has been fundamentally and pervasively transformed by the information technology (IT) revolution. 5/ The widespread diffusion and application of digital micro-electronic technology has given rise to a number of new products and services that have proved to be far superior than those based on electro-mechanical technology. The characteristics of these products, including lower costs, more features and greater reliability, has led to a tremendous expansion of the international market for telecommunications. After expanding annually at more than 12 per cent for nearly a decade, global sales of telecommunications equipment had reached $109 billion by 1985 and are expected to be close to $240 billion annually, at current prices by 1995.

The telecommunications sector in most developing countries has suffered from considerable underinvestment in relation to both demand and economic return. In many countries, subscriber density is extremely low, ranging from a high of 40 telephones per thousand people in Latin America to only 7 per 1000 in many African countries with large areas often averaging less than one telephone per thousand people. Most of the services that do exist are concentrated in urban centres. In Brazil, 70 per cent of telephone lines were in cities accounting for only 20 per cent of the population in 1985, while in Thailand, 89 per cent of the administrative districts containing 75 per cent of the population had no telephones, in 1981. Apart from inconvenience, the economic costs are substantial due to major efficiency losses. There can be little doubt that lack of access to basic telecommunications services is a major constraint for industrial development and overall economic growth.

The convergence of telecommunications, microelectronics and computer technology has provided a new technological base for the telecommunications sector. Old systems have been replaced, previously discrete items of equipment have merged in functions and new components, products and services have been developed. The future possibilities arising from the revolution in digital telecommunciations could yield great benefits. Choices can now be made between several technical options in relation to system, design, component selection and choice of supplier.

Digital exchanges are solid-state and thus less susceptible to breakdowns and require less maintenance than conventional systems. Software control allows continuous adaptation of the exchange to new traffic conditions without changing the hardware. The scope of technical change in transmission technology has bcome rapid and widespread. Coaxial cable technology is being replaced by microwave transmission systems enabling greater efficiency and capacity, with costs falling gradually. Fibre optics and laser transmission systems also offer considerable advantages over conventional systems in terms of greater capacity, speed, flexibility, resistance to interference and significantly reduced installation costs. Microelectronics-based miniaturization has also made the use of satellite communications technology much more economically viable for both public and private networks. The trend towards digital transmission systems can enable developing countries to bypass intermediate technologies and to move directly to a digital transmission infrastructure. Peripheral equipment is also affected by the convergence of computer and telecommunications technology. The range of "intelligent" terminals and telephones, key systems, mobile radios, modems and a variety of office equipment has expanded rapidly. The convergence process in peripherals is leading to the develoment of single devices capable of acting as a terminal for text, data and other non-voice services as well as being used as a telephone. Technical change has generated improvements in all segments of telecommuniations equipment, which can be directly beneficial to developing countries.

Technological developments in telecommunications have been very widespread. Three aspects of implications that are particularly important for developing countries are: (a) lower barriers to entry in production and more sources of supply; (b) changing cost structure for all other industries, including falling unit costs and the proliferation of alternative communications options, and (c) creation of new services and new ways of delivering traditional services. Traditional service industries (banking, insurance, consulting and engineering, tourism, shipping, publishing etc.) are now able to offer a greater range of services, at greater speed and at lower cost through a greatly expanded international telecommunications network. A new category of data services and supplying industries has developed in fields such as data processing and software, and data bases have developed to meet specific user needs. Economies of scale have emerged in the provision of access to flows of data, knowledge and services on a national and international basis.

For a number of developing countries, certain areas can be identified as being broadly suited for changes in current policy and practice. These include: (i) supply of telephones, PABXs and other subscriber equipment by local and/or foreign suppliers, (ii) establishment of separate business networks to meet urgent demand and provide high-quality voice and/or data transmission; (iii) provision of value-added services, such as electronic mail and computer data bases, inventory monitoring, banking networks etc., (iv) allowing private or State operators of dedicated networks to offer services to other users thereby using up space capacity but within a framework established by the PTT, and (v) allowing the contracting or sub-contracting of activities habitually carried out by the PTT, including civil works and maintenance on outside plant, cable ducting and laying and subscriber connection.

Several developing countries are currently installing and expanding their basic telecommunications infrastructure. However, even the scale of investment currently planned is such that developing countries face the task of managing projects of very large dimension. Together, the ten largest countries spent at least an estimated $9.5 billion on telecommuncications equipment in 1987, which is expected to rise to $11.5 billion by 1990. At the country level, these aggregate figures translate into sizeable expenditure of scarce resources. China, with the ninth largest equipment market in the world, for instance, invested $1.8 billion in the telecommunications sector in 1987 out of a total of $5 billion planned by 1990. India, the 12th largest market, invested $1.5 billion in 1987 and Mexico $950 million in the same year out of a planned total of $6.5 billion by 1990, while Brazil spent more than $900 million. These infrastructure investments are occurring at a time when relatively low cost, but flexible digital systems offer developing countries the opportunity to leap-frog from less efficient technologies.

The pervasive role of information technology indicates that any digital capacities created for the telecommunications infrastructure will have wide applicability throughout the economy. The wide range of capacities required to design, manufacture, install and operate digital equipment can also act as a leading edge in the development of human resources and skills. Certain developing countries have achieved notable successes, such as the Republic of Korea and Taiwan Province, where considerable production capability has been developed. Similarly, import-substituting countries such as China, India, Brazil and Mexico have developed considerable production capacity for products based on digital technology.

The changing technology market

The market for industrial technology is undergoing considerable transformation with the advent of fast-changing technologies, processes and products, in informatics, biotechnology and new materials. A new class of entrepreneurs has emerged, and a substantial proportion of innovative processes and applications have been developed or adapted by such new entrepreneurs operating initially through small, research-intensive enterprises in specialized fields of electronics, informatics or biotechnology. In microelectronics and informatics, several new entrants have grown, during the last decade, into major competitors in desk-top and related equipment, systems, and software and in communications and data processing. While major Transnational Corporations (TNCs) such as IBM have been able to retain their position, particularly in specific sectors of electronics production, the range of technological innovation in informatics has extended in several directions and has provided opportunities for several electronics companies, both in hardware and software, to achieve rapid and successful growth. This pattern is likely to continue during the 1990s. In biotechnology also, with the key element of high research intensity, new technological developments have, to a large extent, emanated from relatively small research-oriented companies concentrating in specialized fields of biotechnology. The field of advanced new materials, on the other hand, requires more intensive multi-disciplinary research capability and technical support, generally through large research institutions and enterprises.

The role of major TNCs in various sectors where new technologies are being rapidly extended has been, firstly, to accelerate necessary research to keep ahead, or at least abreast, of technological innovations in their respective fields and, secondly, to develop collaborative links with smaller enterprises undertaking innovative research and applications. Rsearch budgets of major corporations have increased significantly in recent years. Collaborative linkages have, at the same time, been sought to be developed through various arrangements, extending from mergers and acquisitions to contractual financing of specific research. Several examples of such linkages have been provided in subsequent chapters.

In terms of the market for new technologies, recent technologial developments provide a wider range of alternatives. In electronics and informatics, the technology market is marked by several alternative sources, though with a high level of product differentiation. A large number of comparatively new entrants are in a position to supply technology and knowhow for various consumer and industrial electronics, besides software and systems. In telecommunications, while major TNCs still have a fairly dominant role, technology for new processes and products, including peripherals and microelectronic components, are available from a number of additional sources. In biotechnology, where most products are still being researched or tested, several biotech firms, together with major TNCs in chemicals and pharmaceuticals, are engaged in similar fields of research. Once particular products and processes are patented, however, technology sources will inevitably become greatly circumscribed.

Apart from new technologies, there has been much greater diffusion of more mature and established technologies and their related products in recent years. With the expiry of patents on specific products and processes, and with extensive licensing of technology to various countries and enterprises, the technology market has become much broader and alternative sources of technology and knowhow are generally available for most products and processes which are of special interest to developing countries.

New technologies and industrial planning

It must be stressed that if developing-country industries are to compete in global markets, they must incorporate present-day technological processes, such as computer-aided designs and at least partly-computerized manufacture, in their production activities. Without these facilities, they could face considerable competitive disadvantage in a period of rapidly changing products, processes and designs. For effective competition in the major segments of export markets varying degrees of adaptation to computerized production operations may become increasingly necessary. It also appears that industrial projects set up in developing economies will, for the most part, be based on factor conditions other than cheap labour, except where pools of special skills as in computer programming and operations, can be developed. With increased automation, use of robotics, and just-in-time (JIT) delivery, there has been a decline in the establishment and expansion of offshore production units for electronic components, textiles and the like set up by TNCs, during the 1960s and 1970s. Such offshore production, which peaked during the late 1970s, particularly in South-East Asian economies, still continues to be an important feature in these countries and contributes significantly to local employment and export earnings. The number of new offshore units, not only in South East Asia but also in the Caribbean and in Latin American countries has, however, tended to decline.

While the developments towards greater automation, robotics, and JIT may have considerable impact on new industrial investments in developing countries, these countries will continue to have certain factor advantages. Firstly, national markets will need to be served, increasingly through local production enterprises. Secondly, wage differentials still continue to be substantial between industrialized countries and even semi-industrialized developing countries; and if skills in computerized and other operations can be developed, the labour factor will still constitute a significant advantage. This is exemplified in the successful export activities of the Republic of Korea and Taiwan Province in computers, peripheral equipment and a wide range of components to the United States and other developed economies. Thirdly, while robotics and automation can replace several labour-saving operations, the cost element is fairly high. In certain manufacturing sectors such as automobile production, the use of robotics may increase substantially because of the nature of highly-competitive assembly production operations. In production of machinery and equipment, on the other hand, there may be less use of robotics, but flexible manufacturing systems would have greater applicability. To the extent that developing countries can make necessary adjustments, particularly in the development of new skills and capability in computerized designs and production operations, these countries would continue to be viable for a wide range of industrial production, including capital goods manufacture, designed both for local and export markets.

New technologies, particularly the use of computers and advanced automation and communications systems, have obvious implications for local employment. On the one hand, there may be some labour displacement, though the labour displaced is usually employed in other jobs. On the other hand, new jobs are created with higher skills and income, since new products and services of higher quality and efficiency can be developed. Several sectoral studies in industrialized countries have highlighted the fact that substantial rise in productivity can be achieved through automated equipment and computerized techniques with the same or smaller number of employees and, while there may be no direct lay-offs, increase in workforce in the particular enterprise or operation may tend to be reduced. Nevertheless, no categorical conclusions are able to be drawn regarding the impact of electronics technologies on employment. 6/

In developing countries, the effects on employment are more difficult to assess. With respect to automated office equipment, for example, there may be little or no job displacement, but the initial impact may be negative in terms of new employment opportunities which may have emerged. However, such impact may be positive if such techniques are used for new and additional types of work, as is often the case in developing countries. 7/ The increased use of computers in banking, insurance and other financial services, as also in travel, tourism and hotel operations, have now become fairly commonplace in most countries, despite their effects on local employment. In government offices, as also in industrial enterprises, the use of automated equipment, such as computers, word processors and the like, have been accepted as essential features. There has been little job displacement and retraining programmes and facilities have generally been adequate to meet local requirements in most countries. The use of CAD-CAM and FMS in factory operations may, however, face greater complexity and it would be necessary to determine the extent and levels at which CAD-CAM and FMS should be introduced in plant operations. A suitable balance should be achieved between traditional, labour-intensive operations and computerization and automation in different production activities.

The skill requirements for new electronics technologies, highlights the need for an extensive programme for development of new skills and capability in most developing countries. New curricula have to be evolved from the secondary stage and in vocational institutions, while specialized training programmes have to be implemented for development of skills and capability in computer applications and programming and related skills. This would, to a large extent, mitigate any negative effects of new technological applications. In some developing countries, there may be socio-economic problems, which may delay the usage and application of computers and micro-processors. Similarly, the use of numerically-controlled equipment and flexible manufacturing systems and machine centres may be limited only to certain fields. Yet, the trend towards greater computerization and varying levels of technological automation appears to be inescapable. Differences in approach would primarily relate to the timing of such change, even in countries with considerable surplus labour. New job opportunities need to be created through usage of new technologies, which can result in new products and processes and services of higher quality and efficiency.

Usage of new technologies in developing countries

A broad categorization can be made of developing countries in terms of usage and application of new technologies in electronics and informatics and in biotechnology. The first group comprises certain countries in South-East Asia, in particular the Republic of Korea, Singapore, Hong Kong and the Taiwan Province of China, and also Malaysia, Philippines and Thailand, most of which have benefited from offshore electronics assembly. These economies have adjusted satisfactorily to new technological developments in electronics technology and some of these countries have emerged as major exporters of electronics products, including desktop computers, components and peripheral equipment. In certain countries, such as the Republic of Korea and Thailand, considerable research has also been initiated in biotechnology and genetic engineering.

The second group comprises some of the larger developing countries, including Argentina, Brazil, China, India, Indonesia, Mexico and Pakistan. In these countries, there has been considerable growth of indigenous electronics production, including hardware and software, as well as research in biotechnology and new energy sources. Among these countries, development of electronics and informatics has been the highest in Brazil, which has also undertaken considerable research and production activities in biotechnology, new materials and renewable energy technologies. In India also, considerable production and research is taking place in new areas of technology, particularly microelectronics, and biotechnology applications in agriculture and biomass in the field of energy. Similar developments have taken place in other larger developing countries, though policies on foreign investment and foreign technology inflow have differed considerably.

The third group comprises of other developing countries in Latin America, Asia and Africa. The level of technological development differs from country to country but there has been less usage and absorption of new electronics technologies.

The above country grouping indicates that, with the exception of certain countries in South-East Asia and some large developing countries, including Argentina, Brazil, India and Mexico, the impact of new and innovative technological developments and absorption and adaptation in these fields has been fairly limited. There is, however, growing knowledge of the implications and potential of new technologies and policies and programmes are increasingly being focused on various aspects of such developments, as are relevant in specific country situations.

There has been relatively little planning with respect to new technological applications in most developing countries. A number of countries have, however, initiated or encouraged training in computer operations and programming and a pool of talent is gradually developing in these fields. Several research institutions have concentrated on biotechnology applications in agriculture and plant groups, including plant tissue culture. There is also increased research emphasis on biomass and on alternative, renewable energy sources. These developments have been and are likely to be very useful, but they fall considerably short of requirements if developing countries are to keep pace with global developments in new and emerging technologies.

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Table I.1

The substitution of numerically-controlled lathes for conventional lathes in the major OECD machine tool producing countries a/

Year	Production of conventional lathes (Million dollars)	(Per cent)	Production of computer numerically controlled lathes (Million dollars)	(Per cent)
1975	1 147	72	445	28
1976	1 057	62	498	32
1977	1 132	74	626	36
1978	n.a.	n.a.	983	n.a.
1979	1 515	54	1 310	46
1980	1 625	46	1 906	54
1981	1 554	49	1 639	51
1982	885	38	1 416	62
1983	634	33	1 280	67
1984	558	27	1 510	73
1985	542	24	1 714	76
1986	623	22	2 146	78

Source: 1975-1984: Jacobson 1986:16; 1985-1986: elaboration on data supplied by CECIMO.

a/ United States, Japan, France, Italy, Federal Republic of Germany, United Kingdom. Sweden is included in the data for 1975-1984.

Table I.2

The stock of numerically controlled machine tools and the density in their use in selected newly-industrializing and developed countries

Country	Stock a/ (Units)	Density b/
Argentina	500	n.a.
Brazil	1 711	1 033
India	1 178	807
Republic of Korea	2 680	5 176
Singapore	700	4 526
Yugoslavia	1 232	1 720
Germany, Federal Republic of	46 435	11 376
Japan	118 157	22 399
Sweden	6 010	22 177
United Kingdom	32 566	10 505
United Sates	103 308	11 728

Source: Edquist and Jacobsson 1988

a/ The stock data range from 1983 to 1985, whilst the data for the number of employees in the engineering industry are from 1979 or 1980.

b/ Number of NCMTs divided by million employees in the engineering sector.

CHAPTER II

TRENDS IN TECHNOLOGY FLOWS IN DEVELOPING COUNTRIES

The implications and impact of new technological developments for developing countries have to be viewed in the context of the nature and extent of overall technology flows to developing countries and the framework of policies relating to inflow of foreign technology. 1/ Technology flows can be considered and assessed under different categories. At a broad level, such flows can relate to various non-commercial and commercial channels for technological information and transfer between institutions, enterprises and individuals in different countries. Commercial flows of technology involve specific payments for technology, know-how or technological services that may be provided. These can range from payments for machinery and equipment in which technological developments are embodied, to payments involved in licensing of patents and supply of production technology and know-how and to payments for a wide range of technological services.

The various forms of technology flows are closely linked with different forms of participation and contractual arrangements between technology suppliers and recipient enterprises. For developing countries, the most important of these has traditionally been foreign direct investment (FDI) by Transnational Corporations (TNCs), ranging from investments through wholly-owned subsidiaries to affiliates and joint ventures with varying levels of foreign participation. An alternative form may be through a franchise, involving the use of a foreign name, together with provision of specialized expertise, for certain products or services.

Inflow of technology has generally accompanied foreign investments, though the extent of technology transferred has primarily depended on the role ascribed to the subsidiary or affiliate by the parent corporation. During the 1970s, with increased emphasis on national ownership in several developing countries, joint ventures with minority foreign holdings of up to 49 per cent became increasingly popular. This pattern continued during the 1980s also. In the last two decades, however, with the rapid growth of nationally-owned enterprises in several developing countries, there has also been considerable increase in non-affiliate licensing of technology and know-how, not involving foreign equity participation. Considerable technology inflow to developing countries also takes place through contractual arrangements. These can range from machinery supply agreements to turnkey contracts for project implementation or contracts for supply of technology and know-how, or for specialized technical services. With the increase in the pace of industrialization in a number of developing countries, particularly during the 1970s and early 1980s, there has been a substantial increase in such contractual arrangements during this period, both for supply of machinery and equipment and for various technological services.

The extent of technology transfer obviously varies in the case of supply of specific machinery and equipment involving only operational know-how, as compared to contracts for supply of production technology, involving transfer of manufacturing technology or for performance of specific technical services.

It is important, therefore, that a distinction is made between imports of machinery and equipment and trade in technology, as reflected in payments for technology, know-how and technical services.

Imports of machinery and equipment

Innovations in products and processes are often incorporated, in varying degrees, in modifications in related machinery and equipment, although there may be significant time-lag in such absorption. To the extent that technological developments are reflected in various categories and ranges of capital goods, such developments are, therefore, transferred with the machinery and equipment that may be purchased. Trends in capital-goods imports undoubtedly provide valuable information as to the level of technologies that are being used in various sectors.

There has been a significant fall in capital-goods imports by developing countries during the period 1982-1987, as compared to the previous decade. While such imports rose from about $9 billion in 1965 to over $127.9 billion in 1981, there has been considerable decline in subsequent years. An UNCTAD study has assessed that such imports declined by 10 per cent during 1981-1986, as compared to 1970-1981 when an average growth of over 20 per cent was experienced. From the 1981 level, capital-goods imports by developing countries declined to $97.8 billion in 1985 and $107.7 billion in 1986. The sharpest decline has been in developing countries in Latin America and Africa. A significant feature, however, has been the increase in machinery exports from developing countries, which rose to $26.3 billion to industrialized market economies and $11.2 billion to other developing countries during 1986. 2/

Trade in non-embodied technology

International trade in technology is generally considered as relating to non-embodied technology, comprising transfer of intellectual property rights such as patents, trademarks and copyrights on the one hand, and trade secrets and unpatented know-how, together with various technological services, on the other. Transactions with respect to such technology and know-how, as measured in payments for technology, have increased from a total level of over $7.5 billion in 1972, which comprised mostly technology transactions between developed-country enterprises, to a level of $21.8 billion in 1984, also largely between developed-country enterprises, with payments to industrialized market economies amounting to $10.9 billion. 3/ Trends in 1985-1987 suggest that fees and royalties for technology have tended to stabilize during this period. This is at least partly attributable to an overall decline in technology flows to developing countries in recent years.

Outflow of technology and know-how, particularly through technology contracts, has largely taken place from certain industrialized market economies, with the United States continuing to play the most important role, followed by Great Britain, the Federal Republic of Germany, Japan and France and, to a lesser extent, by other West European countries. Technology and know-how in certain sectors has also been supplied to some developing countries by the Soviet Union and other socialist countries from Eastern Europe. A beginning has also been made by some developing countries, particularly Brazil, India and the Republic of Korea, in exports of technology and know-how through technology-supply and service contracts in several fields. Nevertheless, exports of technology and know-how continue, by far, to be dominated by a few industrialized market economies.

The United States has continued to be the principal supplier of technology and know-how, during the 1980s. Income from technology transactions 4/ in the United States increased from $4.3 billion in 1978 to $4.5 billion in 1983, $5.3 billion in 1985 and $9.2 billion in 1988. Payments by United States firms of technology fees and royalties were low in comparison and amounted to only $1.2 billion in 1983, $1.7 billion in 1985 and $3.5 billion in 1988.

Technology licensing by companies from the United Kingdom accounted for receipts of about $1 billion in 1980 5/ and have remained at a level of between $850 million to $1.2 billion during 1981-1987. Imports of technology, mostly from the United States, have accounted for payments of over $800 million in 1980 and have ranged from over $750 million to $900 million in subsequent years. Exports of technology from the Federal Republic of Germany amounted to $548 million in 1980 6/ and have ranged between $450 million to $650 million during subsequent years. Payments for technology by German companies have tended to be higher than receipts, ranging from $900 million to over $1 billion annually. Technology receipts of French companies have ranged between $450 million 7/ to $650 million annually during the 1980s. Payments for technology, mainly to United States companies, have tended to be higher than receipts and have ranged from $800 million to over $1 billion annually, during the 1980s.

In the case of Japan, there was very large inflow of technology during 1960-1980, which has continued during the 1980s also, with total technology payments of $1.3 billion in 1980 to over $2 billion in 1983 and ranging from $1.5 billion to over $2 billion in subsequent years. At the same time, there has been rapid increase in receipts for supply of technology, know-how and technical services by Japanese companies, which rose from $349 million in 1980 and $587 million in 1983 to well over $1 billion in subsequent years. Outflow of technology from Japan has often accompanied foreign investments and has tended to concentrate in the United States and certain West European countries on the one hand and Asian economies, particularly South East Asian countries, on the other.

Technology flows to developing countries

The flow of industrial technology to developing countries, as measured in payments of fees and royalties, slowed and declined during the period 1985-1988. Such payments increased from a total of about $1 billion annually in the early 1970s to around $2.5 billion annually during 1981-1983. Since 1985, however, aggregate payments of fees and royalties by developing countries have tended to decline below $2 billion annually during 1985-1987. Such stagnation and decline is, as pointed out earlier, also reflected in reduced imports of capital goods, and has also been accompanied by a decline in FDI in developing countries.

Foreign investment inflow in developing countries declined during the 1970s, as compared to the 1960s, largely because of nationalization and takeovers of petroleum and mineral companies in several developing countries. During the early 1980s, however, considerable investments, mainly in the manufacturing sector, took place principally in Asian and Latin American countries and FDI in developing countries reached a level of $20.7 billion during 1981 and 1982. In subsequent years, however, FDI in developing countries tended to stagnate and declined to $10.9 billion in 1985 and $10.8 billion in 1986. The stagnation in foreign investments in the latter half of the 1980s also contributed to reduced inflow of technology in these countries.

The extent and number of contracts for supply of technology and know-how would also be expected to fall, together with the decline in FDI and capital goods imports. This has not, however, taken place to the same extent, except in certain developing countries. In several developing countries which have achieved significant levels of industrial capability, such as Brazil, India and the Republic of Korea, the number and range of technology contracts has increased considerably. This has largely been due to policy changes in these countries, which are discussed in the next chapter, as also to the level of technological diffusion and absorption which has enabled enterprises from these countries to avail of technology licensing and specific technical services to a much greater extent than in the 1970s.

The inflow of industrial technology, combined with local adaptations, has resulted in considerable growth of manufacture and production in selected sectors in developing countries. The share of industrial output, as measured in manufacturing value-added (MVA) in 1975, and as projected for 1988 and 1989 may be seen from Tables II.1 and II.2, while Table II.3 indicates sectoral projections.

There has been very wide variation in the pace of industrial growth in particular countries and country-groups. Obviously, with very wide variation in national factor endowments, only broad country groupings can be indicated in terms of transfer and absorption of industrial technology.

The first group of newly-industrializing economies comprises several countries in South-East Asia, particularly the Republic of Korea, Singapore, Taiwan Province and Hong Kong and, to a lesser extent, Thailand, Malaysia and the Philippines. Most of these economies are highly export-oriented. The growth of manufacture in selected newly-industrialized countries, including certain South-East Asian economies may be seen from Table II.4. Table II.5 provides the pattern of growth of exports in various sectors for four of the South-East Asian economies, indicating the wide range of technological absorption.

Another group of newly industrializing countries comprises some of the larger developing countries such as Argentina, Brazil, China, India and Mexico and to a lesser extent, countries such as Indonesia and Pakistan. With sizeable internal markets, these countries have achieved considerable industrial growth and varying degrees of import substitution. Technology inflow has been fairly substantial, both through TNC subsidiaries and affiliates and through non-affiliate licensing by nationally-owned enterprises, including state-owned corporations. Industrial research has also received considerable emphasis and has contributed towards technological adaptation in several fields. In most other developing countries, the extent of technology inflow and absorption has varied from country to country and has taken place, both through TNC subsidiaries and affiliates and joint ventures, or through contractual arrangements by state-owned enterprises. The overall level of technology inflow, particularly with respect to new technologies has, however, been lower than in the case of most South-East Asian economies and some of the larger developing countries.

Trends in technology policies

There has been considerable evolution of policies relating to inflow and transfer of technology in recent years in several developing countries. Special importance was given during the 1970s to the implications of foreign technology and the need to ensure that the inflow of such technologies was on equitable terms and conditions. In the 1980s, with the growing need for technology inflow and absorption, there has been considerable liberalization in policies towards foreign technology in several countries. Such relaxations have often accompanied and been part of liberalized policies and procedures towards foreign direct investments. At the same time, there has also been increased non-affiliate licensing in several developing countries within the framework of national policy parameters and guidelines.

National policies on foreign technology have undoubtedly had significant impact on technology flows to developing countries, although the extent of such impact cannot be quantified. Often, regulatory measures and guidelines have been interpreted in such a manner as to result in restrictions on inflow of much-needed technology. Where rigidly applied, such guidelines have often caused delay and frustration and even the fact of prescribed rules and conditions has served as a deterrent to technology inflow in certain fields. At the same time, policies and institutional measures, where applied with flexibility and pragmatism, have been quite successful in a number of developing countries, and have resulted in considerable improvements in the terms of technology transactions.

A wide range of policies have been undertaken in most developing countries to accelerate the pace of endogenous technological development, particularly scientific and technical education and specialized training facilities, together with the establishment of industrial research institutions. However, the process of industrialization has been based primarily on foreign technology imported through TNC investments or through joint ventures and non-affiliate licensing. The impact of policies directly impinging on technology flows was felt mainly in the 1970s when there was considerable criticism in many developing countries against TNCs and the terms and conditions of foreign technology transfer. This resulted in several developing countries prescribing regulatory control over foreign technology during the 1970s, partly to regulate the activities of TNCs in this field but mainly to improve the terms and conditions of technology transactions. Various mechanisms were set up to regulate and review foreign technology agreements. These ranged from interdepartmental committees, such as the Foreign Investment Board in India, to Registries for Technology as in several Latin American countries or to organizations responsible for industrial property rights as in Brazil and Nigeria. In many other developing countries, such as Indonesia, Singapore and Thailand, however, no control was exercised with respect to foreign technology, and contracts have been left to be negotiated between the enterprises concerned.

In Latin America, specific legislation was enacted in Argentina in 1971 (later amended and finally repealed), Mexico in 1973, the Andean Group countries during the 1970s (although Chile later withdrew from the Andean pact), and in Brazil (Normative Law 15 of 1975). In Asia, specific regulatory measures relating to foreign technology were introduced in the Republic of Korea, Malaysia and the Philippines, while in other countries such as Bangladesh, Pakistan, and several Arab countries, technology-supply agreements were examined as part of the process for approval of new industrial projects. In Africa, technology regulation measures were introduced in Ghana, Kenya and Nigeria, while in other countries, technology contracts were examined as part of the process for approval of foreign investments or of new industrial projects. In countries where technology contracts were subjected to review, fairly detailed guidelines were prescribed with respect to contractual terms and provisions.

Regulatory norms and guidelines

Selection of technology: Developing-country guidelines usually provide that the technology should be appropriate to the needs of the country. While such a principle does not pose any problem, the decision as to the use of a particular technology needs to rest with the user of the technology, the recipient enterprise. The question of appropriateness must be judged in relation to the factor resources and conditions of application. In some cases, the most advanced technologies, involving extensive computerization and automation, may not be suitable. Some of the latest techniques may, however, be quite appropriate such as the use of computer-aided designs for production of ready-made garments for exports. It is obviously not practicable for a technology regulation agency to determine the appropriateness of particular technologies for specific situations. Only certain broad parameters can be defined.

Technology payments: Payments for industrial technology often constitute an area where technology-regulation bodies tend to play an important role. In a number of instances, the level of such payments, either fixed-sum or royalties, have been reduced in the process of review of technology agreements. This undoubtedly represents savings in the costs of acquiring technologies and may be quite justified in most cases. At the same time, if somewhat arbitrary reductions in technology payments are enforced by regulatory agencies, this may affect the relationship between the licensor and licensee enterprise. It may also indirectly lead to increased payments for supply of technological services or of imported inputs, which may be more difficult to control.

Rigidity with respect to technology payments may pose considerable difficulties with respect to inflow of new technologies, particularly microelectronics and biotechnology. With the high costs of industrial research in industrialized economies, and the fairly rapid obsolescence of new products and processes, costs of new technologies may be higher than for mature and established technologies. Alternatively, restricted and lower payments may provide access only to the tail-end of new technological developments. It is essential to ensure a high degree of flexibility in determining payments for new technologies.

Duration: In most developing countries where technology contracts are reviewed, the duration is limited, generally to a maximum of ten years. This is desirable, both in the interests of limiting technology payments to a reasonable period of time, and in order to ensure that effective absorption takes place during such period. However, with fast-changing technologies, duration and renewals of technology contracts should be linked to constant upgrading of technology.

Post-agreement use of technology: A source of some controversy has been the imposition of restrictions by licensors on the use of technology and know-how after expiry of the period of agreement. In most developing countries where agreements are reviewed, such a provision is not permitted.

Patents, trade marks and industrial property rights: A large proportion of technology contracts relate to licensing of patents and industrial property rights. In developing countries, a wider composite package, including know-how and technical services, has also generally to be included. With respect to industrial property rights, particularly patents, there are significant differences in approach between developed and developing countries and modifications in international conventions and treaties in this regard have been under negotiation for some time. In specific technology agreements, however, there should be a listing of patents and a provision that licensors will bear the responsibility for possible infringement of third-party rights. With respect to trade marks, there is a trend towards increased use of local trade names or trade marks, particularly after expiry of technology agreements.

Tie-in provisions for input supplies: An important element in technology agreements is the channeling of supply of imported inputs solely through the licensor which may often lead to inequitable transfer pricing. Guidelines in several developing countries provide that licensees should be free to obtain such inputs from other sources. In actual fact, however, most licensees in developing countries do depend on their licensors for supply of imported inputs. It may be necessary to consider suitable mechanisms for appropriate pricing of such inputs, rather than providing only for option of the licensee to purchase from alternative sources.

Territorial sales rights: With the emphasis on exports from developing countries, several such countries do not permit contractual provisions providing for major restrictions on exports. At the same time, most TNC licensors have exclusive licensing arrangements in a number of countries and are unable to provide unrestricted export rights. This is a matter which can only be resolved through negotiations. The extent of rights to export may, however, be an important determinant in choosing the source for particular technology.

Other contractual provisions: In developing countries where technology agreements are reviewed, norms and guidelines have also been prescribed on several other contractual terms and conditions. These range from guidelines on provisions relating to guarantee or warranty for the technology, access to improvements, and training, to provisions relating to governing law and arbitration and settlement of disputes. These generally present less difficulty in negotiations between licensor and licensee enterprises.

The imposition of norms and guidelines with respect to terms and conditions of technology contracts has undoubtedly had considerable impact on technology contracts in these countries. These have certainly led to improvement in the bargaining position of licensee enterprises in developing countries. At the same time, such regulation may have led to significant restrictions in technology inflow, the extent of which cannot be quantified.

Trends towards liberalization

With the increasing demand for industrial technology, there has been considerable liberalization in regulatory guidelines on technology agreements in several developing countries. This has taken various forms. Firstly, in certain countries, such regulatory measures have been done away with or modified substantially. Secondly, in several countries, regulatory guidelines have been significantly relaxed or are being interpreted liberally. Thirdly, in countries where technology contracts are considered only as part of a proposal for new investments, these are left principally for negotiations between the parties concerned.

In the first category, certain countries such as Egypt and Sri Lanka introduced major liberalization in policies towards foreign direct investments during the first half of the 1970s. In Chile also, major liberalization in policies towards foreign investments took place, after the Allende regime was replaced. Though these changes were designed primarily to promote FDI, for which incentives and facilities were also provided, they also had considerable impact on technology flows which accompanied such investments. Argentina made wide-ranging changes in its technology transfer legislation during the latter 1970s. In the early 1980s, major liberalization with respect to technology transfer guidelines and procedures took place in the Republic of Korea. In the second group, India effected major liberalization in its technology regulations and guidelines during 1984-1985, leading to a significant increase in the number of foreign technology agreements during the period 1985-1988. In the implementation of their technology guidelines, Brazil, Mexico and the Andean group of countries have also been increasingly flexible and liberal in their implementation of technology guidelines. In South-East Asia, Malaysia and the Philippines have also been more liberal in their application of foreign technology guidelines. In the third group of countries, increased liberalization has largely taken the form of leaving technology transfer arrangements largely to the parties concerned.

The situation with respect to technology flows to developing countries at the end of the 1980s is likely to be substantially different from what prevailed at the beginning of this decade. Firstly, the demand for industrial technology, particularly new technologies, is likely to increase sharply and the stagnation and decline in technology flows during 1986-1988 is likely to be reversed during the 1990s. Secondly, with increased knowledge and awareness of the intricacies of technology negotiations, the need for rigid regulatory guidelines is likely to become substantially reduced. Thirdly, with greater reconciliation of interests of host developing countries and TNCs, there is likely to be increased technological participation of TNCs and proprietors of technology in enterprises in developing countries. This is likely to lead to considerable growth in non-affiliate licensing and joint ventures. Finally, there is very substantial scope for increased technological co-operation between developing countries, which should rise significantly in the 1990s. Countries such as Brazil, India, the Republic of Korea, Singapore and others are in a position to supply a wide range of technologies to other developing countries and much greater technology transfer between such countries may take place in the next decade.

Notes and references

1/ This chapter, and the succeeding chapter, are largely based on a UNIDO study on "Trends in Technology Flows to Developing Countries and Related Policies", Technology Trends Series No. 12, UNIDO document IPCT.127(SPEC.), 21 November 1989, by Rana K.D.N. Singh (UNIDO consultant).

2/ UNCTAD, "Recent trends in international technology flows and their implications for development", TD/B/C/6-145, Geneva, August 1988.

3/ UNCTAD, op. cit.

4/ U.S. Department of Commerce, Survey of Current Business, June 1989, pp. 66-67.

5/ Department of Industry, United Kingdom, Business Monitor - Overseas Transanctions (various issues).

6/ Deutsche Bundesbank, Federal Republic of Germany.

7/ Ministère de l'Economie, des Finances et du Budget, Statistiques et Etudes Financières.

8/ Bank of Japan, Balance of Payments Monthly.

Table II.1

Percentage share of developing countries in global MVA
(Based on constant 1980 US dollars)

1970	9.8
1975	11.2
1988 (projected)	13.8
1989 (projected)	14.1

Source: Industry and Development, Global Report 1988/89, UNIDO, 1988.

Table II.2

Average annual growth rates of MVA
(Based on constant 1980 US dollars)

	Developing countries	Developed countries
1975-85	4.6	3.0
1985-89	6.7	3.8

Source: Same as Table 1.

Table II.3

Estimated share of industrial output (MVA) of developing countries in world total in 1975 and projected shares for 1988 and 1989

(Percentage)

ISIC		Share of developing countries in world total			Average annual growth			
			Projected		Developed countries		Developing countries	
		1975	1988	1989	1975-1985	1985-1989	1975-1985	1985-1989
3	Manufacturing	11.2	13.8	14.1	3.0	3.8	4.6	6.7
311	Food products	16.1	19.9	20.3	2.4	3.0	4.9	4.1
321	Textiles	20.9	24.1	24.8	1.2	2.4	2.3	5.5
322	Wearing apparel	13.2	17.4	18.0	1.2	1.8	3.4	5.6
323	Leather and fur products	14.9	17.2	17.7	0.4	1.6	1.3	4.5
324	Footwear	15.5	20.0	20.5	0.7	0.1	2.5	4.2
331	Wood and wood products	11.1	11.7	12.1	1.5	4.4	3.2	2.3
341	Paper and paper products	8.8	11.4	11.7	3.5	4.7	5.7	7.5
351	Industrial chemicals	8.9	13.5	14.0	3.7	3.8	8.0	6.8
352	Other chemical products	16.1	19.1	19.5	4.0	4.6	6.0	5.5
356	Plastic products	12.0	14.5	14.8	5.8	6.5	7.5	8.7
371	Iron and steel	8.1	14.9	15.5	0.6	1.3	5.1	9.0
372	Non-ferrous metals	8.6	11.4	11.7	2.4	3.3	4.9	5.7
381	Metal products	8.4	12.3	12.6	2.2	3.0	4.8	8.4
382	Non-electrical machinery	4.4	4.7	4.8	4.4	4.4	3.3	9.8
383	Electrical machinery	6.7	10.8	11.2	6.3	5.6	8.3	16.1
384	Transport equipment	7.2	8.3	8.5	2.9	3.9	3.6	6.9

Source: UNIDO statistical data base.

Table II.4

Manufacturing growth in newly-industrialized countries

	Share of world manufacturing output (per cent)				Average annual growth in manufacturing (per cent)		
	1963	1970	1980	1986	1960-1970	1970-1980	1980-86
Hong Kong	0.08	0.15	0.22	0.29	...	10.1	7.1
Korea, Rep. of	0.11	0.22	0.49	0.92	17.6	15.6	12.5
Singapore	0.05	0.06	0.11	0.12	13.0	9.7	0.9
Taiwan Province of China	0.11	0.23	0.46 a/	...	15.5 b/	11.5 c/	...
Brazil	1.57	1.73	2.03	1.80	...	8.7	-0.6
Mexico	1.04	1.27	1.40	1.30	9.4	7.1	-0.7
Portugal	0.23	0.27	0.24	0.22	8.9	4.5	-0.1
Yugoslavia	1.14	1.25	0.77	0.86	5.7	7.1	3.0

Source: Dicken, P., Global shift: Industrial change in a turbulent world, London, 1988; UNIDO data base.

a/ 1977; b/ 1961-1970; c/ 1971-1978.

Table II.5

Growth and structure of exports by group of manufactures for selected Asian countries 1975, 1985
(Percentage)

	SITC	Product group	Average annual growth rate of exports, 1975–85	Share in total exports of manufactures 1975	Share in total exports of manufactures 1985
Hong Kong	65	Textile yarn, fabric	8.7	9.6	6.2
	84	Clothing	11.2	44.3	35.6
	85	Footwear	10.0	1.2	0.8
	69	Metal manufactures	11.8	2.7	2.3
	71	Non-electrical machinery	27.3	2.2	6.9
	72	Electrical machinery	15.7	12.5	15.1
	83	Travel goods	8.3	2.0	1.3
	86	Instruments, watches	23.5	3.9	8.9
Republic of Korea	0 (part of)	Food products	3.2	5.7	1.2
	65	Textile yarn, fabric	14.5	14.4	8.7
	84	Clothing	14.5	25.4	15.3
	85	Footwear	23.2	4.2	5.3
	63	Wood manufactures	-11.0	5.0	0.2
	67	Iron and steel	22.9	5.1	6.3
	69	Metal manufactures	28.7	2.6	5.1
	71	Non-electrical machinery	30.9	1.7	3.9
	72	Electrical machinery	23.4	9.8	12.4
	73	Transport equipment	42.4	4.1	21.6
Singapore	0 (part of)	Food products	5.9	4.8	1.9
	4	Animal, vegetable fats	21.1	2.3	3.6
	65	Textile yarn, fabric	10.5	2.9	1.8
	84	Clothing	16.4	2.7	2.8
	332	Petroleum products	13.1	40.0	31.3
	67	Iron and steel	9.2	2.0	1.1
	71	Non-electrical machinery	21.4	8.5	13.4
	72	Electrical machinery	20.6	14.0	20.8
	73	Transport equipment	13.1	5.1	4.0
	86	Instruments, watches	10.3	2.8	1.7
Thailand	0 (part of)	Food products	10.4	60.9	39.8
	65	Textile yarn, fabric	17.8	7.2	9.1
	84	Clothing	26.8	4.8	12.5
	85	Footwear	60.5	0.1	1.8
	61	Leather	35.4	0.2	1.1
	62	Rubber manufactures	31.1	0.3	1.0
	63	Wood manufactures	11.8	2.0	1.5
	66	Non-metal mineral manufactures	4.8	2.5	1.0
	67	Iron and steel	30.0	0.5	1.5
	68	Non-ferrous metals	7.6	10.3	5.2
	69	Metal manufactures	15.0	1.0	0.9
	71	Non-electrical machinery	45.8	0.4	3.8
	72	Electrical machinery	33.9	2.1	9.4

Source: Handbook of industrial statistics 1988, UNIDO, 1988.

CHAPTER III

TECHNOLOGY POLICIES AND FLOWS IN SELECTED DEVELOPING COUNTRIES

It is proposed, in this chapter, to deal with technology policies and flows of industrial technology, including new technologies, in selected developing counries. It may be difficult to establish a direct and causal relationship between the implementation of certain policies and the level of technology inflow. Nevertheless, national policies on foreign investment and technology, and on related aspects such as intellectual property rights, undoubtedly have an impact on technology flows. Policy distinctions in this regard cannot be sharply defined and differences in policy measures can often be fairly blurred. Nevertheless, it is possible to categorize countries on the basis of, firstly, whether foreign technology contracts are screened and reviewed in acordance with specific policy norms and guidelines; secondly, if the conditions of technology transfer are taken into consideration as part and parcel of a proposed investment which requires governmental approval, and thirdly, where foreign-owned or nationally-owned enterprises are not required to submit foreign technology contracts for any form of approval.

The first category of developing countries, where technology inflow is regulated, includes several countries ranging from Brazil, Mexico and the Andean Group of countries in Latin America, India, Malaysia and the Philippines in Asia, and Ghana, Kenya, and Nigeria from among countries in Africa. Information on technology flows and trends in most of these countries has been provided. The second group, comprising those countries where approvals are required for industrial projects but not specifically for foreign technology contracts, cover a number of developing countries. Information on technology flows has been compiled for some of these countries. The third category comprises a large number of developing countries where no approval of foreign technology contracts is necessary, including certain countries where earlier regulatory measures have been removed or significantly modified. The countries covered in this category include Argentina, Chile and the Republic of Korea.

Brazil

Brazil experienced rapid industrial growth during the 1960s and early 1970s and, despite periods of slowdown in the mid-1970s and during 1986-1988, because of the serious debt crisis, there has been sustained and extensive industrial and technological diversification in most production and service sectors. Policies on foreign investment have been liberal, with total foreign direct investments (FDI) reaching a level of over $25 billion in 1986. Since the mid-1970s, however, foreign technology inflow has taken place within the framework of a well-defined system of regulation of technology agreements. Regulatory control over foreign technology in Brazil, including restrictions in imports of computers and systems, has been combined with major emphasis and resource allocations for endogenous research in a number of Brazilian enterprises and institutions. This has resulted in rapid technological growth of Brazilian companies in most sectors, including the computer industry. At the same time, inflow of technology in Brazil has been fairly substantial during the 1980s. While prescribed guidelines are being implemented, the National Institute of Industrial Property (INPI) has been fairly liberal in their interpretation.

Technology flow in Brazil has covered most sectors of industrial production. By 1985, a strong base with respect to capital goods manufacture had been created, as also in chemicals, plastics and textiles. This can be seen from Table III.1, at the end of this chapter. This pattern has continued during the period 1985-1988, when there has been a significant shift towards electrical, electronics and communications technology, besides capital goods, chemicals and other sectors. This may be seen from Table III.2.

The total number of contracts (1093) in 1988 was the highest since 1979-1982, during which period the number of contracts averaged about 1200 annually. While the number of contracts, by itself, may not be an accurate indicator of the nature and extent of technology flows, it does suggest that the decline in technology inflow, which took place during 1983-1986, is gradually being reversed, particularly with respect to inflow of contemporary technology in electronics and informatics and in chemicals and plastics.

The number and percentage of different types of technology contracts, namely, patent licences, know-how agreements, technical co-operation contracts and contracts for specialized services, during 1979 to 1988, may be seen from Table III.3. This indicates a substantial increase in patent and know-how agreements and a reduction in agreements for specialized services.

Mexico

After decades of stable industrial growth till the 1970s, Mexico has been facing serious economic difficulties in recent years, largely due to its high external indebtedness. The pace of industrialization slowed down during the early and mid-1980s. With respect to foreign investments and technology inflow, Mexico promulgated specific legislation on both these issues in 1973. While the law on FDI provided for Mexican majority holdings, except in exceptional circumstances, the law for registration of technology contracts provided certain specific guidelines as to contractual conditions governing such contracts. During the 1980s, the law on technology transfer was amended in 1981 and provided greater flexibility. In the same year, a law on development of computer facilities provided for several incentives in this sector. A law in 1984 provided for legal protection for computer software. A new patent law was passed in 1985 which provided patentability of chemical and pharmaceutical products after a 10-year transition period. A law on technology development in 1985 defined rules and procedures for co-ordination of technological development.

The implementation of the laws on foreign investments and technology contracts in Mexico has, in general, improved the terms and conditions of such contracts for Mexican enterprises and has also provided a more prominent role for Mexican partners and shareholders in new joint ventures. While there have been exceptional cases where majority foreign holdings have been permitted in Mexico, the practice in general has been to limit foreign holdings to 49 per cent. With respect to technology contracts, the establishment in 1973 of a Registry where foreign technology contracts were reviewed and registered had a salutary impact on the terms and conditions of technology transactions in Mexico. Over the years, the Mexican Registry for Technology has also gathered valuable information on technology trends in various sectors and has been able to provide considerable assistance to Mexican enterprises on technology choice and contractual terms and conditions.

Information on foreign investments and on technology contracts in Mexico is provided in Table III.4 for the period 1983-1987. During this period, the Commission on Foreign Investments approved 1439 applications, involving investments of over $7 billion. These included 149 applications for new projects and 135 applications for setting up new companies.

Despite the country's continuing economic difficulties, the flow of FDI and technology has continued in Mexico at a fairly satisfactory pace in recent years. The implementation of guidelines on technology contracts has been fairly flexible and pragmatic.

Andean Group countries

The Andean Group of countries, comprising Bolivia, Colombia, Chile (which later withdrew), Ecuador, Peru and Venezuela entered into the Cartagena Agreement and its follow-up measures in the early 1970s for a joint approach towards foreign investments and technology agreements. Decision 84 of the Agreement provided guidelines for authorization, registration and control of foreign investments and for foreign technology contracts. Various provisions were made for the regulation of technology agreements in accordance with fairly detailed norms on specific contract conditions. During the 1970s, while the concept of a joint approach towards foreign direct investments and technology had been maintained in principle, the guidelines were liberalized considerably in 1987 and the provisions of Decision 24 were significantly revised with respect to the region's policies towards foreign investments and technology transfer. Trends in foreign direct investments in the Andean Pact countries indicated slow growth in the early 1980s, which may be seen from Table III.5. This pattern has not changed significantly in subsequent years. The flow of technology has been closely related to foreign investments and was largely confined to certain sectors. Most foreign investments were in the manufacturing sector, followed by petroleum and minerals. The details in this regard may be seen from Table III.6. Inflow of technology, as reflected by the number of technology contracts, has largely been in the manufacturing sector, where 2,391 contracts were entered into up to 1985. Most of these contracts were with United States companies (1,135 constituting 47.5 per cent), followed by EEC countries (29.7 per cent). Out of the 36 technology agreements in the mining, as also the agricultural, sectors, 19 were with United States companies. The total number of technology contracts registered up to 1,985 in the Andean Group countries came to 2,782.

Chile

The withdrawal of Chile from the Andean Group of countries took place in the latter 1970s as part of the liberalized approach towards foreign investments and technology, following the change of Government in 1975. Apart from measures encouraging greater flow of such investments and technology, a new law relating to intellectual property was passed in 1985, which provided protection to computer programmes. The flow of technology, as measured by payments of fees and royalties, increased considerably during the early 1980s and stabilized at a lower level in subsequent years. This may be seen from Table III.7.

The number of technology contracts registered up to end-1986 included 121 related to petroleum, chemicals and pharmaceuticals; 568 to the automotive and metal-transformation industries, 10 to electronics; 32 for agro-industries, fisheries and food and tobacco; 22 for computer software, and 19 for services. During 1986, however, 86 technology contracts were entered into or renewed, mostly in the petroleum, chemicals and pharmaceutical sectors (27 contracts), metal-transformation (14), and in computer software (13 contracts). During 1987, the number of contracts increased to 112, mostly in chemicals and pharmaceuticals, computer software and in textiles and shoes. In 1988, 98 technology contracts were entered into in Chile, mostly with respect to chemicals and pharmaceuticals (36), and in agro-processing and food industries (18).

In Latin America, as a whole, varying degrees of regulatory control over technology contracts have continued in most countries, with the exception of Argentina and Chile, during the 1980s. Despite such regulation, there has been considerable flow of technology in various sectors, including in electronics and informatics in recent years. This has largely been due to pragmatic and flexible interpetation of guidelines on technology contracts in Brazil, Mexico and the Andean Group countries. In Chile, on the other hand, the number of technology contracts increased significantly during 1986-1988, suggesting a substantial increase in technology inflow.

In Argentina, where technology regulation was introduced in the early 1970s, there was a major change in 1981 when the law on transfer of technology was substantially amended, allowing considerable freedom in technology transactions to enterprises. A new policy on electronics and informatics was prescribed in 1984 and a National Commission on Informatics was set up in order to accelerate the pace of electronics development in the country. Despite internal difficulties, the pace of technological absorption and diffusion has been fairly high in Argentina since the late 1970s. The industrial targets for the information technology sector in Argentina can be seen from Table III.8.

Asian countries

As in the case of most Latin American countries, varying degrees of regulatory control, direct or indirect, are exercised with respect to technology inflow in a number of Asian countries. The nature of such policies and the pattern of technology inflow is examined below for certain Asian countries, namely, India, Malaysia, the Republic of Korea and Thailand.

India

India experienced fairly steady industrial growth over the last two decades, with a high level of technological diffusion and absorption in most production and service sectors. The number of technology contracts approved by the Government rose to 6232 by 1980. During the period 1969-1979, by far the majority of such contracts did not involve foreign equity, and such participation took place only in 15 per cent of the contracts during this period, and was limited to below 30 per cent in most cases. Most of the technology contracts related to production of machinery and equipment, chemicals, pharmaceuticals and a wide range of intermediate products. During the 1980s, with increased liberalization of regulatory guidelines, technology inflow increased considerably. In 1980, 526 technology contracts were approved by the Government. During 1982-1985, the number of such contracts increased steadily, to reach a level of 1024 approved contracts in 1985 and between 900 to 1100 contracts annually in subsequent years, including a number of technology agreements in electronics and telecommunications. A significant change has been the increased proportion of technology contracts involving foreign equity ownership, the proportion of such contracts rising to over 30 per cent in 1988, though the maximum foreign holdings have been mostly limited to 40 per cent.

Total payments for technology, by way of fees and royalties, were of the order of around Rs1000 million towards the end-1970s, but rose substantially to over Rs3000 million annually during the latter half of the 1980s. The number of technology agreements approved in India annually during 1948 to 1986 may be seen from Table III.9. A similar number were approved during 1987-1988. The sectoral distribution of technology inflow (1976-1986) may be seen from Table III.10. Agreements approved during 1987-1988 follow a similar pattern.

The Indian guidelines prescribed in 1969 and as amended from time to time have ensured that technology inflow has taken place on acceptable terms and conditions. Such inflow has also enabled Indian-owned enterprises, both state-owned and private, to expand and diversify rapidly, with the role of foreign subsidiaries becoming limited. It is difficult, however, to envisage the extent of technology inflow that might have taken place in India if unrestricted inflow of foreign investments and technology had been permitted. Much of such investments may well have taken place in non-priority sectors and for various consumer products involving substantial outflow of foreign exchange. At the same time, there may have been greater technological diversification and strengthening of the country's technological base. Nevertheless, India's technological absorption and capability has grown rapidly and is very impressive in most fields, although it continues to lag behind industrialized countries in the fast-growing areas of microelectronics and informatics.

Malaysia

By the end of the 1970s, the manufacturing sector had become the most dynamic and fastest-growing sector in Malaysia. The share of manufacturing in GDP rose from 8.7 per cent in 1960 to 12.2 per cent in 1970 and 20.5 per cent in 1980.

The flow of technology in Malaysia, as reflected in contractual agreements, has increased rapidly in recent years. As shown in Table III.11, between 1970 and 1987 a total of 1432 agreements were approved, with increasing numbers since 1980. While such agreements averaged less than 60 a year during the 1970s, the average number nearly doubled in the period after 1980. Japan accounts for a substantial proportion (32.2 per cent) of all agreements signed between 1975 and 1987. Other important sources are the United Kingdom and the United States, accounting for 13.7 and 10.6 per cent, respectively. Japan has also become the principal supplier of machinery (34-40 per cent), while machinery imports from the United States accounted for an average of 26 per cent. Table III.12 indicates that a large proportion of the agreements signed between 1975 and 1987 are in the electronics and electrical industries (17.7 per cent), fabricated metal industries (10.8 per cent), and chemical industries (12.3 per cent). Table III.13 provides the number of technology agreements and royalty rates for various industries.

Philippines

The Philippines have registered fairly satisfactory industrial growth over the last two decades. The geographical distribution of FDI flows in the Philippines can be seen from Table III.14. The extent to technology flows, as measured by payment of fees and royalties may be seen from Table III.15. A flexible and pragmatic policy has been followed in reviewing foreign technology contracts. Fairly detailed guidelines have been provided in this regard.

Thailand

Thailand has liberal procedures and incentives for foreign direct investments, with the Board of Investment determining the level of incentives in particular cases. Technology contracts are not reviewed by any governmental body and are left for negotiations between the enterprises concerned. Such contracts are, however, registered with the Central Bank and constitute the basis on which remittances of fees and royalties are permitted.

There has been considerable inflow of technology in Thailand and, by 1981, there were 689 contracts, involving 438 companies in Thailand, with remittances amounting to 1330 million Baht in that year. During the period 1981-1988, the number of contracts grew rapidly, averaging 200-250 contracts each year and extending to a variety of modern technologies, including electronics and telecommunications. The industrial distribution of FDI for the period from 1970 to 1987 may be seen from Table III.16. Total remittance relating to FDI including payments for technology by firms in Thailand may be seen from Table III.17. In general, Thailand has experienced rapid industrial growth during the 1980s. The pace of technological absorption has also increased considerably in recent years.

Republic of Korea

The spectacular industrial success achieved in the Republic of Korea should be viewed against the background of a system of technology regulation in the 1970s and major liberalization of such regulations during 1980-1981. A Technology Development Promotion Law was enacted in 1967 and revised in 1972 to develop the country's technological capability. A Technology Transfer Centre was set up in 1976 to review technology contracts and also to assist Korean industry in identifying and evaluating relevant technologies. Detailed guidelines were prescribed by the Centre for reviewing foreign technology contracts.

The approach towards foreign technology inflow underwent significant change towards the end of the 1970s, when a far more liberal approach was adopted. The liberalization of regulatory measures commenced in 1979 and was expanded substantially in the next year. Basically, the approval system for technology agreements was greatly simplified and greater latitude was given to enterprises negotiating technology contracts. In 1979, a system of automatic approval was implemented for agreements in heavy industries and for contracts with a duration of less than 3 years and initial payment of less than $30,000 and running royalty of up to 3 per cent. In 1980, the automatic approval system was extended to several sectors for agreements of up to 10 years or involving payments of up to 10 per cent royalty and down payment of over $US 500,000 or, in the case of outright purchase of technologies, up to $US 1 million. Agreements with indefinite duration were also permitted in priority sectors where technological changes occurred rapidly. Following the liberalization of technology regulation measures, inflow of technology increased rapidly. The number of technology agreements rose to 222 in 1980 and to 247 in 1981. By end-1981, nearly 57 per cent of the agreements were with Japanese companies, followed by 13.6 per cent with United States companies.

Several other measures were enacted during the 1980s. In 1982, tax exemptions were provided on income from exports based on patent rights and from licensing of patents within the country. In 1982, there was considerable liberalization of controls over foreign investments and, in 1985, there was further relaxation of controls over imports of technology. The Patent Law was comprehensively revised in 1986, while a new copyright law extended copyright protection to computer software. The Trademark Act of 1986 increased penalties for trademark infringements.

Table III.18 provides the industrial distribution of foreign investment flows during 1979 to 1987, while royalty payments and receipts are indicated in Table III.19.

African countries

Among African countries, foreign technology contracts are reviewed by governmental agencies in certain countries such as Nigeria, Ghana and Kenya. The institutional arrangements vary, although the coverage of the guidelines tend to be similar. In most other African countries arrangements for technology supply are considered as part of the overall proposal for new investments.

Nigeria

The legal and institutional framework for dealing with foreign technology in Nigeria is the National Office of Industrial Property (NOIP) Decree No. 72 of 1979. Under this enactment, all technology agreements entered into with foreign partners by Nigerian companies must be registered with NOIP, which provides the institutional framework for handling technology inflow and foreign technology contracts in Nigeria. Table III.20 indicates the number of agreements submitted to NOIP during 1983-1987. The number of registered technology agreements according to regional sources may be seen from Table III.21. Table III.22 provides information on sectoral distribution of technology agreements during 1987, indicating the nature of technological flows and diversification.

Kenya

Kenya has had fairly sustained growth over the last two decades, with GNP per capita increasing at an average annual rate of 2 per cent during 1965-1985. The country's economic strategy stresses rapid increase in private-sector investments, including foreign capital inflow, which have served as a major source of investment and industrial technology. Foreign equity inflow in the manufacturing sector was of the order of $44.9 million during 1974-1978, $39.9 million during 1979-1983, and $28.3 million during 1984-1987. In the services sector, foreign investments increased from $3.19 million in 1974-1978 to $15.69 million during 1979-1983, and $27.7 million during 1984-1987. The growth of the manufacturing sector, though limited, has extended over several subsectors.

With the emphasis on attracting new investments and technology inflow, a fairly liberal policy has been adopted towards foreign technology contracts. Such contracts are reviewed in the Central Bank of Kenya, by a committee consisting of representatives of the Ministries of Finance and Industry, besides the Central Bank. Certain broad guidelines are observed in the review of such agreements but, by and large, such agreements are left to the enterprises concerned. The nature and extent of foreign equity and technology flows in recent years in various sub-sectors of the Kenyan economy can be seen from Table III.23.

Arab countries

Considerable importance has been accorded in recent years to the development of endogenous technological capability in Arab countries. In Egypt, a National Technology Policy was announced in 1984, with the Academy of Scientific Research and Technology playing a leading role in its implementation. Broad criteria have also been defined for technology choice and contracts. In Jordan, Law No. 30 of 1987 provided for the establishment of the Higher Council for Science and Technology. In Iraq, a Department for Science and Technology has been set up, besides laws on foreign direct investments and industrial property. In Algeria, a 1973 law (Avis 72 of February 1, 1973) dealt with financial aspects of technology transfer and provided for registration of all contracts. The organization dealing with industrial properties, INAPI, is responsible for contracts involving such rights. In Kuwait, legislation relating to industrial growth established an Industrial Development Committee which is responsible, inter alia, for approving technology transfer projects. In Saudi Arabia, while proposals for new industries require the approval of the Ministry of Industry, technology contracts are left to the parties concerned. In most other Arab countries, including Morocco, Sudan and Tunisia, certain aspects of technology transfer are considered as part of the review of foreign investment proposals or of new industrial undertakings. The Ministry of Industry is generally the principal department dealing with technology imports as part of industrial projects. In some countries, such as Tunisia, a committee reviews technology-supply proposals from economic and technical angles. Detailed guidelines for reviewing technology agreements have not generally been prescribed and considerable flexibility is exercised in most Arab countries with respect to technology contracts.

Inflow of foreign technology to Arab countries has increased substantially during the last 15 years. Most such technology has related to infrastructure development and to the petroleum and petrochemical sectors in petroleum-exporting Arab countries. Much of such technology has been supplied through turnkey projects, implemented under the supervision of foreign companies and contractors, but a large number of joint ventures have also been established. At the same time, there has also been substantial inflow of industrial technology with respect to a wide range of consumption goods and intermediate products. With technology agreements largely left to the enterprises concerned, including state-owned undertakings, there has been considerable freedom on the part of such enterprises in negotiating suitable terms and conditions for technology inflow. The magnitude of technology and equipment flows to several Arab countries may be seen from Table III.24.

The above review of developing-country experience with respect to technology flows and technology policies has highlighted present policies and trends in certain developing countries and regions. It has obviously not been possible to deal with all, or even most, of the developing countries. The experience in several of these countries is undoubtedly of great interest. The Joint Venture Law, followed by other legislation, including the Patent Law in China, resulted in considerable inflow of technology to China during 1983-1988. In Indonesia, inflow of foreign technology has been fairly substantial during the 1980s, together with the volume of foreign direct investments. With the BKPM in Indonesia serving as a one-stop agency for foreign investments and technology, procedures for dealing with such cases have been considerably streamlined. In Turkey, technology inflow has continued at a fairly steady pace, with 254 technology agreements during 1981-1985, as against 813 agreements during 1963 to 1981. A significant development has also been the major emphasis now being given to foreign investment and foreign technology inflow by certain socialist developing countries, namely, Angola, Ethiopia and Viet Nam. These trends and the growing needs of developing countries for industrial technology suggest that the range and volume of technology inflow to developing countries will increase significantly during the next decade and that national policies will be largely oriented to this goal.

Table III.1

Brazil: Production of principal manufacturing industries, 1985

(Percentages)

Industry	*Share of value. 1980*	*Change of volume. 1985*
Non-metal products	4.1	7.5
Metallurgy	13.8	7.0
Machinery	7.8	10.1
Electrical equipment	5.3	19.3
Transport equipment	7.7	11.7
Pulp and paper	2.8	6.4
Chemicals	19.1	6.5
Plastics	2.1	11.3
Textiles	6.9	13.6
Clothing, shoes and woollens	3.5	7.5
Food products	13.8	0.1
Total including others	100.0	8.3

Source: Fundaçao Instituto Brasileiro de Geografia e Estatistica.

Table III.2

Brazil: Contracts in principal sectors, 1979-1988

Sector / Year	1979	1980	1981	1982	1983	1984	1985	1986	1987	1988
Mineral extraction	134	131	117	103	81	37	49	116	109	98
Production of metals	47	44	40	52	35	33	28	26	29	14
Metallurgy	263	261	291	160	145	106	73	115	126	115
Mechanical	179	201	142	161	120	126	141	122	197	222
Electrical and telecommunications	63	48	38	62	77	59	55	75	150	179
Transport	86	80	50	71	60	60	43	52	39	51
Chemicals	129	108	98	98	58	58	79	89	99	109
Pharmaceuticals	8	6	4	7	7	1	5	1	2	2
Textiles	57	70	43	59	47	40	29	27	37	49
Food processing	10	8	7	15	13	5	9	7	9	4
Services (electrical)	65	69	83	82	37	35	36	18	37	81
Commercial	2	1	1	1		2	4	3	6	2
Consultancy	102	95	77	70	44	40	27	25	19	37
Engineering services	49	46	37	46	37	9	11	14	16	9
Scientific institutions	6	6	15	28	17	12	10	15	21	22
Others	145	112	105	107	95	81	64	81	67	99
Total	1.345	1.286	1.148	1.122	873	704	663	786	963	1.093

Source: INPI/DIRCO.

Table III.3

Brazil: Number and percentage of technology contracts, by categories, 1979-1988

Category / Year	Patent Licences		Knowhow agreements		Techn. Co-operation contracts		Specialized services		All categoreis		Trademark licences		Total / Total
	No.	%	No.	%	No.	%	No.	%	No.	%	No.	%	
1979	85	5,5	130	8,3	147	9,4	983	62,9	1345	86,1	217	13,9	1562
1980	83	5,2	100	6,3	194	12,2	909	57,1	1286	80,9	306	19,2	1592
1981	63	4,1	75	4,9	105	6,9	905	59,3	1148	75,2	378	24,8	1526
1982	112	7,3	146	9,6	127	8,3	737	48,3	1122	73,5	405	26,5	1527
1983	118	8,3	95	6,7	98	6,9	562	39,7	873	61,6	544	38,4	1417
1984	111	8,7	89	7,0	109	8,5	395	30,8	704	55,0	577	45,0	1281
1985	94	6,8	83	6,0	103	7,5	383	27,7	600	43,4	718	52,0	1381
1986	92	6,7	102	7,5	86	6,3	506	37,0	786	57,5	582	42,5	1368
1987	148	7,4	170	8,4	96	4,8	549	27,2	963	47,7	1053	52,2	2016
1988	135	7,2	236	12,5	78	4,1	633	33,6	1082	57,5	800	42,6	1882

Source: INPI/DIRCO.

Table III.4

Mexico: Foreign direct investments, 1983-1987
(In million US dollars)

Projects	Total a/		1983		1984		1985		1986		1987 a/	
	Value	Per cent	Value	Per cent	Value	Per cent	Value	Per cent	Value	Per cent	Value	Per cent
Number of projects	10,295.4	100.0	683.7	100.0	1,442.2	100.0	1,871.0	100.0	2,420.9	100.0	3,877.2	100.0
Authorization by Commission	7,348.4	71.4	393.7	57.6	796.6	55.2	1,337.6	71.5	1,559.8	64.4	3,260.7	84.1
Capital contributions	2,946.6	28.6	290.0	42.4	645.6	44.8	533.4	28.5	861.1	35.6	616.5	15.9
Capital increase by existing enterprises	2,881.0	28.0	282.0	41.2	617.4	42.8	526.7	28.1	846.6	35.0	606.3	15.7
New enterprises	65.6	0.6	8.0	1.2	28.3	2.0	6.7	0.4	14.5	0.6	8.2	0.2

Source: Secretaria Ejecutiva de la C.N.I.E., Dirección General de Inversiones Extranjeras.

a/ Preliminary.

Table III.5

Andean Group: Foreign direct investments (accumulated) in Andean Group countries

(In million US dollars)

Country / Year	1981	1982	1983	1984	1985
Bolivia	458,2 2/	494,2	505,3	524,0	529,2
Colombia	1 200,7	1 314,2	1 431,4	1 741,2	2 230,7
Ecuador	1 037,7	1 091,3	1 135,3 3/	1 207,5	1 267,6 */
Perú	1 126,8	1 190,8	1 311,4	1 361,0	1 412,9 */
Venezuela	1 768,0	2 020,7	2 189,3	2 275,0	2 396,9 */
SUBREGION	5 591,4	6 111,2	6 572,7	7 108,7	7 837,3

Source: Sisteema Andino de Infromac'ion Technologica (SAIT).

1/ Does not incclude investments in hydrocarbons in Colombia, Ecuador, and Venezuela.
2/ Revised figures.
3/ For January-September only.
4/ Estimates.

Table III.6

Andean Group: Foreign direct investments (cumulative) in Andean Group countries, by sectors of activity 1/

(In million US dollars)

Sector	1981	%	1982	%	1983	%	1984	%	1985 2/	%
Agriculture and fisheries	92,8	1,7	97,6	1,6	113,0	1,7	122,5	1,7	130,7	1,7
Petroleum and minerals	994,3	17,7	1 110,8	18,2	1 145,1	17,4	1 369,8	19,3	1 827,1	23,4
Manufacturing	2 817,6	50,4	3 141,0	51,3	3 419,1	52,0	3 645,0	51,3	3 803,6	48,8
Electricity, gas and water	153,2	2,7	148,8	2,4	147,9	2,3	148,3	2,1	149,0	1,9
Construction	67,0	1,2	76,5	1,3	82,0	1,3	82,1	1,1	81,9	1,0
Commerce	481,2	8,6	510,8	8,4	520,8	7,9	545,7	7,7	568,1	7,3
Transport and communications	75,2	1,4	77,4	1,3	76,7	1,2	76,3	1,1	77,2	1,0
Banks and insurance	870,8	15,6	908,4	14,9	994,6	15,1	996,9	14,0	1 032,6	13,3
Other services	39,3	0,7	39,9	0,7	73,5	1,1	121,8	1,7	125,0	1,6
Total	5 591,4	100,0	6 111,2	100,0	6 572,7	100,0	7 108,4	100,0	7 795,2	100.0

Source: SAIT.

1/ The data for Colombia, Ecuador and Venezuela do not include the hydrocarbon sector.

2/ For Venezuela, the data are up to November 1985.

Table III.7

Chile: Payments of royalties for technology contracts

Period	Amount in 000 US dollars
1978	15 859
1979	20 161
1980	28 919
1981	38 890
1982	33 155
1983	32 351
1984	25 617
1985	23 108
1986	25 695
1987	21 939
1988	28 858

Source: Banco Central de Chile, Santiago.

Table III.8

Argentina: Industrial targets for the development of the information technology sector

Data processing	Telecommunications	Industrial Electronics
Class 0 and 1 systems based on microprocessors, including maintenance	Public exchanges and their peripherals	Process control systems of less than 1,000 points
Class 2 systems (minis and supermicros)	Private exchanges	Programmable controllers
Peripherals of the above-mentioned classes (except removable hard disks)	PCM and TDM channels[1]	Numeric control system
Local networks based on micros	Modems	Small robots
Bank, commercial and office automation		Instruments based on micros
		Agrarian electronics
		Nuclear electronics
Custom and semi-custom integrated micro-components		

[1] Digital multiplexers for voice or data transmission.
Source: Comisión Nacional de Informática, "Informe", p. 23.

Source: table VII-3, p. 126. "Informe", p. 23, quoted in Economic and Social Progress in Latin America, Special Section on Science and Technology, Inter-American Development Bank, Washington, D.C. 1988.

Table III.9

India: Foreign collaboration approvals, 1948-1986

Total	Total number of cases approved	Cases involving foreign capital participation
1948-55	284	-
1956	82	-
1957	81	-
1958	103	-
1959	150	-
1960	380	-
1961	403	165
1962	298	124
1963	298	115
1964	403	123
1965	241	71
1966	202	49
1967	182	62
1968	131	30
1969	134	29
1970	183	32
1971	245	46
1972	257	36
1973	265	34
1974	359	55
1975	271	40
1976	277	39
1977	267	27
1978	307	44
1979	267	32
1980	526	65
1981	389	56
1982	588	113
1983	673	129
1984	740	148
1985	1041	256
1986	960	256
Total	10987	2176

Table III.10

India: Foreign collaboration approvals, by industry, 1976-1986

Year	Alternate/ Renewal Sources of Energy	Industrial Machinery	Electricals & Electronics	Chemical Industry	Mechanical Engg.	Metal-lurgical	Machine Tools	Textile	Trans-portation	Others	R&D and Consultancy	Total
1976	-	57	63	32	13	12	19	2	19	60	-	277
1977	-	74	67	23	4	7	10	2	19	61	-	267
1978	-	76	48	30	7	18	20	2	22	84	-	307
1979	-	72	52	24	15	12	14	-	26	52	-	267
1980	-	121	114	52	29	31	26	6	41	106	-	526
1981	-	*96	*55	*27	*49	*9	*5	*5	*19	*42	-	389*
1982	3	110	134	54	125	36	6	7	24	82	7	588
1983	5	144	149	76	69	24	24	3	34	134	11	673
1984	4	169	162	85	99	32	27	7	25	120	10	740
1985	14	215	315	69	89	54	38	13	52	162	20	1041
1986	5	87	246	135	145	69	28	16	54	175	-	960

* There were 82 cases cleared under delegated power by various Administrative Ministries. These 82 cases are included in the total figure of 389 but are not included in the sectorwise breakup.

Table III.11

Malaysia: Types of agreements, 1970-1987

Type of Agreement	1970	1971	1972	1973	1974	1975	1976	1977	1978	1979	1980	1981	1982	1983	1984	1985	1986	1987	Total	Per cent
1. Technical assistance and know-how	9	15	33	34	28	27	30	21	48	54	57	64	48	61	71	51	50	53	754	(52.6)
2. Management	-	1	13	5	3	12	7	7	11	13	13	6	10	13	10	6	10	5	145	(10.1)
3. Joint venture	-	2	7	6	7	6	6	4	7	8	14	22	14	14	17	9	19	11	173	(12.1)
4. Service	4	2	9	5	5	12	5	1	12	3	6	7	2	7	2	1	1	1	85	(5.9)
5. Trademarks/patents	3	2	4	3	6	1	5	-	4	4	4	8	8	7	1	19	33	30	142	(9.9)
6. Turnkey and engineering	-	-	-	-	-	-	-	-	-	-	5	5	4	4	6	-	1	-	25	(1.9)
7. Others a/	-	-	-	-	-	-	-	-	-		15	19	8	25	12	10	9	10	108	(7.5)
TOTAL	16	22	66	53	49	58	53	33	82	82	114	131	94	131	119	96	123	110	1 432	(100.0)

Source: Ministry of Trade and Industry.

a/ Others include supply and purchase, sales, marketing and distribution.

Table III.12

Malaysia: Agreements by industry groups, 1975-1987

Type of Agreement	1975	1976	1977	1978	1979	1980	1981	1982	1983	1984	1985	1986	1987	Total	Per cent
1. Electronics and electrical	17	9	5	21	15	19	16	19	15	21	20	12	29	218	17.7
2. Fabricated metal	8	3	5	7	16	6	14	7	12	3	9	22	21	133	10.9
3. Chemical	3	-	4	19	8	11	21	5	15	17	16	15	18	152	12.3
4. Transport equipment	5	4	-	5	7	10	11	11	22	17	20	15	4	131	10.6
5. Food	4	7	2	2	8	14	15	4	21	6	10	8	8	109	8.9
6. Textiles	6	7	2	4	-	8	5	2	5	6	1	7	2	55	4.5
7. Basic metal	-	5	3	3	5	7	10	13	5	5	1	1	2	60	4.9
8. Wood and wood products	4	1	6	5	4	-	-	4	1	6	-	4	1	36	2.9
9. Pulp, paper, printing and publishing	-	-	-	-	-	-	-	-	-	-	3	4	1	8	0.6
10. Rubber and rubber products	6	-	1	2	5	8	14	2	7	5	4	13	8	75	6.1
11. Non-metallic mineral products	1	6	1	1	7	5	4	16	9	17	7	7	12	93	7.6
12. Hotel and tourist complex	-	5	1	-	2	4	2	4	8	7	4	4	1	42	3.4
13. Plastic	1	-	2	-	3	5	4	1	2	7	-	4	-	31	2.5
14. Other	3	6	1	13	7	17	13	6	9	2	1	7	3	88	7.1
TOTAL	58	53	33	82	87	114	131	94	131	119	96	123	110	1 231	100.0

Source: Ministry of Trade and Industry.

Table III.13

Malaysia: Number of agreements, by industry and royalty rates, 1985-1987

Industry	< 1%	1-1.99%	2-2.99%	3-3.99%	4-4.99%	5-5.99%	6-6.99%	7-7.99%	8-8.99%	9-9.99%	> 10%	Total
Food, Beverages and Tobacco	3	3	6	4	2	4						22
Textiles and Wearing Apparel	6	2	2	2								12
Paper & Paper Products		1	1	1		1						4
Chemicals	7	6	15	7	1	3						39
Rubber Products	2	3	7	9	2	1	1			1		26
Non-Metallic Mineral Products	4	6	9	4				1				24
Basic Metals	2	1	2	1								6
Fabricated Metal Products	2	6	6	1	1							16
Machinery (except electrical)	1		2	2	1	1						7
Electrical Machinery & Appliances	8	11	16	4		5						44
Transport Equipment	6	5	15	6	1	1	2					36
Professional & scientific & measuring, & controlling equipment			1									1
Wholesale Trade	1	1										2
Retail Trade	1											1
Hotels	1		4		2	3		1				11
Total	44	45	86	41	10	19	3	2		1		251

Note : a. Royalty rates are based on net sales
b. A total of 385 agreements were registered, while 251 agreements involved royalty payments

Source : Ministry of Trade and Industry .

Table III.14

Philippines: Industrial distribution of foreign direct investment flows, (inward investment), 1979-1987

(In million US dollars)

	1979	1980	1981	1982	1983	1984	1985	1986	1987
PRIMARY	0.49	7.07	7.15	24.86	7.50	0.85	2.17	0.84	3.80
Agriculture	0.33	3.58	7.03	1.38	1.29	0.82	1.97	0.66	3.39
Mining & quarrying	0.16	3.49	0.13	23.48	6.21	0.03	0.19	0.18	0.40
SECONDARY (Manufacturing)	105.91	34.18	19.52	26.98	24.09	25.41	68.90	32.16	36.66
TERTIARY	7.92	12.01	7.18	21.69	6.94	8.52	9.15	10.43	35.50
Construction	0.27	0.20	0.49	3.59	0.99	0.25	0.05	0.22	0.09
Wholesale & retail trade	2.55	1.56	3.19	5.02	1.01	1.52	1.18	4.86	10.81
Trans., storage & comms.	0.31	3.46	0.52	1.26	0.27	0.17	0.51	0.37	2.51
Fin., insur. & busi. services	4.64	5.75	2.85	11.53	4.42	6.44	1.73	4.80	21.70
Electricity, gas & water	-	0.45	-	0.01	0.04	-	-	-	0.02
Community, social & personal services	0.15	0.59	0.13	0.26	0.21	0.14	5.68	0.19	0.35
TOTAL	114.31	53.26	33.85	73.52	38.52	34.78	80.21	43.43	75.95

Source: Securities and Exchange Commission, Philippines

Notes to Table IIE:

1. Exch. Rate: Pesos/Dollar	7.378	7.511	7.900	8.540	11.113	16.699	18.607	20.386	20.568

2. Investment refers to initial paid-in capital and increases in paid-in capital in domestic stock corporations and partnerships.

3. Nationality of investor is based on citizenship. Thus, amounts include investments by resident aliens funded from local sources and without any inward remittance of foreign exchange.

Table III.15

Philippines: Royalty receipts and payments, 1978-1987

(in million US dollars)

	PAYMENTS	RECEIPTS
1978	17.40	0.01
1979	18.06	0.02
1980	19.37	0.02
1981	23.56	0.04
1982	23.32	0.05
1983	22.71	0.57
1984	0.51	0.02
1985	26.24	0.01
1986	20.22	-
1987	30.95	0.03

Source: Dept. of Econ. Research, Central Bank of the Philippines

Notes:

1. Data cover copyright and patent royalties.
2. Data prior to 1978 not available.

Table III.16

Thailand: Industrial distribution of foreign direct investment flows (Inward investment)

(in million baht)

	1970	1971	1972	1973	1974	1975	1976	1977	1978	1979	1980	1981	1982	1983	1984	1985	1986	1987
Primary	18.7	52.6	175.8	48.1	1,194.7	64.4	88.2	91.1	49.3	158.8	806.5	775.2	1,697.7	1,502.4	2,854.8	592.8	442.4	477.9
Agriculture	0.0	0.0	4.9	5.0	15.2	2.1	1.3	(0.2)	(18.2)	4.6	209.8	7.5	15.6	48.2	67.6	77.0	202.2	285.9
Mining and quarrying	8.4	9.2	35.87	18.4	20.2	28.6	11.6	68.0	39.2	9.0	155.9	37.1	150.4	354.6	132.3	85.8	3.8	(59.3)
Oil exploration	10.3	43.4	135.1	24.7	1,159.3	33.7	75.3	23.6	28.3	145.2	440.9	730.6	1,531.7	1,099.6	2,654.9	430.0	236.4	251.3
Secondary	446.9	110.7	308.3	608.7	1,030.8	582.1	458.8	659.1	465.4	723.9	1,011.9	2,526.1	1,230.9	2,567.5	3,167.0	1,358.2	2,123.8	4,754.4
Food	45.8	12.5	5.3	26.7	237.3	82.3	30.1	61.7	17.1	51.8	91.3	156.9	(257.3)	217.7	105.9	394.8	286.9	436.6
Textiles	138.6	34.5	177.9	433.1	378.3	192.6	158.6	415.9	127.4	(10.4)	(1.5)	(32.2)	420.7	13.2	452.5	59.8	85.7	995.7
Metal and non-metallic	11.7	15.7	3.0	3.4	118.4	22.1	4.9	2.5	32.5	32.9	47.8	149.0	123.5	1,022.2	78.3	(125.7)	(22.6)	365.1
Electrical appliances	18.3	27.9	46.3	37.0	111.6	110.1	129.2	126.4	189.9	351.4	448.2	624.4	666.7	394.0	1,045.3	280.1	617.0	1,136.5
Machinery and transport equipment	22.4	4.7	(27.0)	15.4	57.8	1.8	(0.8)	161.1	33.2	59.1	92.1	129.5	227.3	421.6	119.8	32.0	(14.9)	159.9
Chemicals	78.8	(43.8)	68.1	111.9	67.0	91.6	136.9	(2.0)	66.0	73.3	213.4	177.5	106.5	350.3	283.3	488.4	484.0	868.1
Petroleum products	99.8	50.3	20.9	(33.2)	(20.0)	43.3	0.8	(140.4)	67.5	126.7	2.2	1,246.8	(129.1)	0.0	934.2	0.0	8.2	(15.8)
Construction materials	4.4	2.5	9.2	7.7	26.9	7.0	0.0	4.0	(100.0)	(29.4)	1.3	12.5	8.8	19.1	5.8	38.3	5.4	11.5
Others	27.0	6.4	4.6	6.7	53.3	31.1	(1.0)	29.8	31.8	67.9	117.1	61.8	63.8	129.3	141.9	190.4	674.1	796.8
Tertiary	424.9	645.2	943.0	948.2	1,610.9	1,098.3	1,067.2	1,413.3	620.2	244.9	2,059.8	3,113.2	1,459.2	4,155.0	3,623.5	2,452.3	4,341.9	3,816.7
Construction	93.6	222.6	315.6	132.7	96.7	168.6	152.3	227.0	190.4	293.8	782.6	1,276.8	736.9	741.6	1,066.2	1,585.3	1,234.9	1,349.1
Trade	234.0	303.0	332.7	446.5	226.5	545.4	436.4	306.4	347.8	341.3	750.6	479.6	699.0	1,697.7	1,893.6	1,082.9	1,783.4	852.0
Transportation and travel	38.6	45.1	119.5	62.3	(17.2)	(21.7)	241.9	235.4	63.6	94.5	214.9	333.0	263.4	199.4	185.1	198.0	255.6	220.6
Financial institutions	51.9	49.6	127.1	169.7	1,276.7	392.9	218.3	606.1	(5.4)	(546.3)	(173.0)	674.2	(480.3)	996.5	150.3	(1,279.2)	510.2	444.4
Housing and real estate	0.0	0.1	33.4	48.6	9.1	0.1	7.6	29.7	9.0	3.4	150.9	14.1	(3.8)	94.8	94.6	305.5	42.7	328.2
Hotels and restaurants	0.0	0.2	2.9	69.0	7.6	13.6	5.8	(5.1)	1.8	1.9	87.7	91.7	137.5	35.6	92.3	222.8	100.3	94.7
Other services	6.8	24.7	11.8	19.4	11.6	(0.5)	4.8	14.0	12.9	56.4	246.2	243.7	106.1	389.5	141.4	337.2	414.8	527.7
Total net inward investment flows	890.5	808.4	1,427.1	1,604.9	3,836.3	1,744.8	1,614.2	2,163.8	1,134.8	1,127.6	3,878.2	6,414.4	4,387.9	8,224.8	9,645.3	4,403.3	6,908.1	9,049.0

Source: Derived from Bank of Thailand data.

Notes: 1. For the period 1970-1977, it was not possible to separate outward from inward investment. However, the outward investment during that period was probably very small. 2. The total figure for 1978 was 124 million baht higher, because there was no country breakdown of outard invetment for that year.

Table III.17

Thailand: Total remittances related to foreign direct investment flows a/

(Million baht)

Year	Profits & Dividends	Management Fees	Royalty & Technology Fees	Interest	Total Remittance Outflows (1)	Total Net FDI Inflows (2)	(1)/(2)
1970	576	53	66	378	1,073	891	120.5%
1971	585	45	100	478	1,207	808	149.3%
1972	566	44	131	510	1,250	1,427	87.6%
1973	646	59	164	664	1,532	1,605	95.5%
1974	903	78	178	1,392	2,551	3,836	66.5%
1975	1,410	63	255	1,587	3,315	1,745	190.0%
1976	1,613	121	257	1,410	3,400	1,614	210.7%
1977	1,635	159	338	1,504	3,637	2,164	168.1%
1978	1,661	153	402	2,492	4,707	1,011	465.6%
1979	1,972	185	457	4,321	6,935	1,048	661.9%
1980	2,049	146	610	6,264	9,069	3,816	237.7%
1981	3,406	515	816	8,881	13,619	6,363	214.0%
1982	2,714	569	873	6,408	10,564	4,339	243.5%
1983	2,714	736	934	6,066	10,450	8,192	127.6%
1984	2,902	832	1,161	7,349	12,245	9,624	127.2%
1985	3,588	808	1,238	9,246	14,880	4,379	339.8%
1986	2,962	832	1,250	7,957	13,000	6,880	188.9%
1987	3,663	929	1,454	6,814	12,860	4,712	272.9%

Source: Compiled from Bank of Thailand data.

Note: a/ Breakdowns according to whether payments are made to affiliates or not are not available. Data on receipts are not available but are likely to be negligible.

Table III.18

Republic of Korea: Industrial distribution of foreign direct investment (inward investment) 1/

(In million Won)

	1977	1978	1979	1980	1981	1982	1983	1984	1985	1986	1987	Total
PRIMARY	2,036.67	287.98	471.90	175.55	266.97	1,016.93	301.76	723.77	758.64	4,239.79	1,598.25	9,553.56
Agriculture	1,738.04	118.58	346.06	131.86	170.26	771.29	65.16	723.77	227.06	2,799.49	1,155.71	6,410.66
Mining and quarrying	298.63	169.40	125.84	23.69	96.71	245.64	236.60	-	531.58	1,440.30	442.54	3,142.90
Oil	-	-	-	-	-	-	-	-	-	-	-	
SECONDARY (manufacturing)	43,527.58	45,665.87	58,919.54	59,923.56	76,974.78	81,742.06	54,668.66	103,594.20	145,877.11	213,756.04	308,366.67	1,098,822.62
Food, beverages, tobacco	931.22	514.49	5,403.38	377.21	8,093.36	4,488.83	6,259.53	9,897.43	3,668.87	15,792.94	32,207.73	86,189.28
Textile, leather & clothing	707.12	525.62	51.79	136.06	542.10	2,382.59	1,395.57	1,748.17	194.88	5,549.61	8,023.35	20,024.12
Paper and allied	-	-	244.42	817.60	1,778.85	5,023.25	38.79	801.14	4,167.40	386.08	250.88	13,508.41
Chemicals and allied	25,169.94	19,004.74	21,550.58	28,905.16	36,551.56	29,839.03	12,059.81	19,124.29	25,072.23	29,560.31	57,912.22	260,575.19
Coal and petroleum products	2,436.94	5,964.82	2,247.70	5,054.43	340.52	194.47	-	3,929.96	-	-	10,130.51	21,917.59
Non-metallic	155.85	1,235.65	954.93	515.71	839.71	367.00	65.94	644.78	522.88	7,004.00	5,108.16	16,023.11
Metals	4,490.07	1,415.70	3,698.73	3,498.80	9,025.69	897.04	1,102.34	4,019.42	2,928.49	1,748.80	5,710.28	32,629.59
Mechanical equipment	2,553.58	4,029.78	10,126.25	4,170.61	4,056.21	1,814.54	1,688.03	4,939.85	5,250.57	15,056.93	21,240.40	68,343.39
Electrical equipment c/	5,362.72	9,145.66	7,509.74	11,164.56	15,423.97	19,879.53	19,173.44	50,162.58	32,993.77	35,011.19	129,453.59	320,772.37
Motor vehicles	1,013.50	2,950.95	1,789.35	4,651.09		15,495.97	12,009.39	6,920.14	68,879.48	98,920.73	30,564.23	239,230.38
Other transport												
Other manufacturing	706.64	878.46	342.67	632.33	322.81	1,359.81	875.82	1,406.44	2,198.54	4,725.45	7,745.32	19,609.19
TERTIARY	23,620.17	41,629.81	40,126.50	19,442.01	25,052.36	11,269.60	40,047.32	51,465.85	58,746.36	202,899.21	204,583.03	653,632.24
Construction					6,170.13	193.74	729.20	8,147.65	17 215.96	-	7,392.44	39,849.12
Wholesale and retail trade			4.84	168.87	47..67	489.09	77.58	80.60	12,403.88	2,051.13	558.53	15,882.19
Transport and storage	198.44	2,290.29	1,502.82	7,012.17	2,683.94	525.65	617.50	736.67	568.12	-	491.07	14,137.94
Finance, insurance and business services	6,317.17	7,658.33	24,103.20	7,876.54	5,258.91	7,602.50	21,458.02	11,100.76	17,544.82	4,959.04	14,238.69	114,142.48
Communications												-
Other services d/	17,104.56	31,681.19	14,515.64	4,384.43	10,891.71	2,458.62	17,165.02	31,400.17	11,013.58	195,889.04	181,902.30	469,620.51
TOTAL	69,184.42	87,583.66	94,517.94	79,541.12	102,294.11	94,028.59	95,017.74	155,783.82	205,382.11	420,895.04	514,547.95	1,762,008.42

Source: Ministry of Finance, op. cit.

a/ Arrival basis.
b/ Including fishery annd forestry.
c/ Including electronics and communication equipment.
d/ Including hotels.

Table III.19

Republic of Korea: Royalty receipts and payments, 1972-1987

(In million Won)

	PAYMENTS	RECEIPTS
1972	4,032	
1973	4,577	
1974	7,124	
1975	12,845	
1976	14,725	
1977	28,009	
1978	41,172	145
1979	45,464	920
1980	65,136	3,945
1981	72,941	8,036
1982	84,578	13,306
1983	115,982	14,662
1984	171,860	13,540
1985	257,083	9,331
1986	362,276	10,294
1987	430,800	7,945

Sources: Ministry of Science and Technology, The Korean Yearbook of Science and Technology (various years); Korea Industrial Technology Promotion Association, Major Statistics on Industrial Technologies, 1988.

Table III.20

Nigeria: Comparative data on number of agreements submitted to NOIP according to industrial sector (1983-1987)

Industrial sector	Agreements submitted to NOIP				
Agro-based sector	73	44	88	68	36
Chemical/mineral based sector	48	31	98	90	60
Light/heavy engineering sector	89	31	78	64	25
Service sector	21	10	13	18	10
Total	231	116	227	240	131

Table III.21

Nigeria: Number of registered agreements according to sources of technology by industrial sector in 1987

Industrial sector	North South America	United Kingdom/ Western Europe	Asia	Others	Total
Agro-based sector	1	15	2	-	18
Chemical/mineral based	6	24	4	-	34
Engineering sector	3	17	1	-	21
Services sector	2	6	-	-	8
Total	12	62	7	-	81

Table III.22

Nigeria: Technology agreements evaluated in 1987 by industrial sector

Industrial sector	Submitted agreements (Number)	Registered agreements (Number)	Agreements abandoned (Number)	Agreements rejected (Number)	Agreements pending (Number)
Agro-based sector	36	18	-	2	16
Chemical and mienral base sector	60	34	-	2	24
Light and heavy engineering	25	21	-	-	4
Services	10	8	-	1	1
Total	131	81	-	5	45

Table III.23

Kenta: Subsectoral foreign exchange transaction with foreign business interests
(In million US dollars)

Subsectors	(1) Equity Inflows 1974-87	(2) Equity Inflows 1979-87	(3) Equity Inflows 1984-87	(4) Total Fees 1979-84	(5) Total Fees 1984-87	(6) Royal-ties 1984-87	(7) Divi-dends 1984-87	(8) Interest Payments 1984-87	(9) Fees (1984-1987) Mgt.	(10) Fees (1984-1987) Tech.	(11) Fees (1984-1987) Other
Finance, Banking, Insurance	33.20	32.21	20.69	4.29	2.55	0.49	27.92	23.30	2.18	0.31	0.06**
Tourism, Hotels	4.47	3.84	0.83	2.75	1.79	0.33	4.89	4.76	1.48	0.29	0.02**
All Other Services	8.87	7.30	6.14	7.36*	4.79	0.16	10.58	11.93	0.03****	1.13	3.63**
Food, Beverages, Tobacco, and Agro-Business	34.77	26.34	12.45	29.47	7.01	1.12	61.70	19.80	3.99	2.99	0.03**
Textiles, Fibres	18.99	5.22	1.42	4.44	1.23	0.10	2.07	3.60	0.67	0.56	0.00**
Footwear, Leather, Apparel	0.86	0.18	0.18	1.13***	0.62	0.00	5.41	0.25	0.00	0.62	0.00**
Paper, Pulp, Printing, Publishing	1.94	0.50	0.48	10.79	3.29	0.90	8.50	7.44	0.67	2.62	0.00**
Raw material processing	10.41	8.75	0.48	6.71	2.24	0.05	0.97	4.34	0.00	2.09	0.15**
Chemicals, Pharmaceuticals	18.79	10.50	5.24	16.25	7.28	2.20	45.00	19.57	0.04	4.87	2.37**
Metallic, Non-metallic products	13.19	8.23	5.22	5.83	3.61	0.95	14.83	4.98	0.06	3.55	0.00**
Rubber, Tires, Plastics	3.15	1.46	1.24	7.49	4.66	0.52	10.54	0.75	0.00	4.66	0.00**
Mechanical and Engineering goods (non-electrical)	n.a.	n.a.	n.a.	1.22**	0.45**	0.00**	1.51****	1.27	0.00	0.00	0.45**
Electrical machinery, Appliances	6.21	5.16	0.28	3.07	0.96	0.99	5.62	43.17	0.00	0.96	0.00**
Office equipment, Data process	n.a.	n.a.	n.a.	n.a.	n.a.	0.37	1.84****	n.a.	0.00	0.00	0.00**
Motor Vehicles and Transport Equipment	4.70	1.78	0.35	5.13	2.05	0.02	n.a.	24.45	1.91	0.14	0.00**
Other Manufacturing	0.10	0.00	0.00	n.a.	n.a.	0.27	6.11	n.a.	0.00	0.00	0.30**
T O T A L	159.65	111.57	56.00	105.93	42.53	8.47	207.49	169.41	10.36	24.08	7.01**

Note: *Missing 1980;
**Missing 1987;
***Missing 1984, 85, 87;
****Missing 1985;
n.a. - no year data available

Source: From unpublished data researched and compiled in the Central Bank of Kenya.

Table III.24

Arab countries: Technology contracts among six developed countries and 15 Islamic countries of the Middle East

Supplier	*Type of contract* Technical services	Equipment supply	Construction	Total
		(billions of dollars)		
Total amount	$4.4	$10.8	$13.6	$28.8
		(Percentage)		
Six major industrial countries	46.1	69.1	76.1	68.9
Other	23.2 [c]	30.3 [d]	16.2	22.5
Local and Middle East	30.7	0.6	7.6	8.5
		(billions of dollars)		
Six major industrial countries	$2.0	$7.4	$10.3	$19.7
		(Percentage)		
United States	75.5	37.2	43.6	44.4
Japan	3.4	16.5	7.9	10.7
Federal Republic of Germany	2.8	10.2	7.0	7.8
United Kingdom	16.3	11.6	1.5	6.8
France	0.2	21.5	30.9	24.3
Italy	1.9	2.9	9.1	6.1
Total major industrial countries	100	100	100	100

Source: *Technology transfer to the Middle East*, Washington D.C., United States Congress, Office of Technology Assessment, September 1984.

a Sectors covered: communications, commercial aircraft support systems, medical services, and petrochemical facilities. Incomplete coverage, especially for 1978-79 and 1982.

b Saudi Arabia, Iran (Islamic Republic of), Algeria, Egypt, Iraq, Kuwait, Libyan Arab Jamahiriya, United Arab Emirates, Syrian Arab Republic, Lebanon, Jordan, Qatar, Oman, Yemen Arab Republic, P.D.R. Yemen.

c Comprised entirely of one large Canadian communications technical services contract (Bell of Canada).

d Comprised primarily of a few Sweden/Netherlands telecommunications equipment contracts.

CHAPTER IV

ELECTRONICS AND INFORMATICS

Developments in electronics and information technologies have accelerated rapidly in recent years and continuing innovations in products and processes are having major impact on several production and service sectors. 1/ The diffusion of these technological developments to developing countries has been slow and gradual and is still mainly confined to a few of these countries. Because of their pervasive nature, the impact will, however, inevitably extend to all economies. Apart from their effects on industrial competitve capability, which have been discussed in the first chapter, electronics and information technologies will bring about major changes in a number of fields. Developing countries need to assess their situation in relation to these developments and to determine policies and programmes for technology inflow, absorption and adaptation in these fields.

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. 2/ By 1986, computers and software amounted to over one-third of the total and this proportion has by and large, been maintained during 1987-1988. The major exporters of electronics products may be seen from Table IV.1.

The electronics and informatics sector comprises of a wide range of technologies, processes and products, extending from hardware, components, software and systems to a wide range of technological applications in data processing, telecommunications, industrial production, and other sectoral applications, and to a great variety of consumer electronics products. The miniaturization of electronic components and application of digital technologies have resulted in substantial price reduction for products such as micro-computers, peripherals and other hardware and enabled radical improvements in their performance. There has also been close and growing convergence in technological developments and applications between computers and telecommunications, which has led to a major new role for informatics services and capability. 3/ The electronics sector, which was clearly segmented 15 years ago, is now increasingly being merged. At one end are powerful micro-circuits, which serve as systems themselves, while, at the other, are specific operational systems, such as private-branch switching. It is such product continuumm that is implied in the convergence between electronics and informatics. 4/

Technical developments in the density of integration of the basic elements of electronics development, namely, chips and memories, has made it possible to incorporate information processing machines into most activities. Requirements in respect of increased density of integration for processing even larger quantities of information, remain potentially very considerable and open up the possibilities of operating in all these activities with improved performance. It is possible to envisage the continuance of a very rapid rate of progress in the intensification of such integration while still remaining on the same technical lines. This implies that production of the basic electronics elements will continue the same innovative trends. One must count not on a halt or a slowing down but the maintenance of the rate of evolution of performance of integrated circuits between now and the year 2000. This trend will be continued with equally rapid developments in the other module, the microprocessor.

The technical evolution with respect to micro-processors will be the massive diffusion of these basic modules for information processing, so that by the middle of the 1990s, the annual production is likely to exceed one billion micro-processors. 5/ The convergence of computers and communications is also leading to the development of a series of automation technologies with wide-ranging applications. These technologies, some of which are still in the process of emergence, extend to photonics and lasers, and to robotics and artificial intelligence. The versatility and information-processing capability through micro-processors and other developments in electronics are also bringing about major transformation in equipment and processes, ranging from computers, word processors and automated office equipment to numerically-controlled machine tools and robots, and to usage of new satellite technologies, fibre optics and other innovative developments in communications. The use of electronics equipment and applications is also increasing rapidly in several other sectors such as in the medical field, particularly in diagnostic applications; in agro-processing and the agricultural sector; in macro-economic and energy planning, and a variety of other applications which would be of special interest to developing countries. 6/

The electronics industry has several features and characteristics which make this sector unique and of special significance, particularly with respect to the range of technological innovations and applications. The range of application extends, firstly, to specific electronic products, particularly micro-processors, and components, including semiconductors, and secondly, to the great diversity of their usage in various fields such as data processing, communications, industrial applications, office automation and the like. As such applications get increasingly extended to new fields of economic activity, the nature of such activity itself tends to undergo major transformation. 7/ As discussed in the previous chapter, the utilization of CAD-CAM techniques and flexible manufacturing systems (FMS) is having major impact on production processes in several industrial sectors, particularly metal-transformation and engineering-goods industries, and on the machinery requirements for such industries. The use of machine tools is increasingly moving towards numerically-controlled (NC) machine tools, which can be utilized for flexible production. The higher productivity, efficiency and precision achieved through flexible automated manufacture will have increasing impact on costs, quality and competitive capability of resultant products. Varying degrees of automation will be extended to a wide range of production processes and will bring about considerable industrial restructuring, particularly in the capital-goods sector, including automotive equipment. These will also affect developing countries such as Brazil and India, which have been exporting engineering-goods products and machine tools. Similarly, office automation, including desk-top computers, input-output devices, storage devices, calculators, duplicators and facsimile equipment, which have undoubtedly transformed office operations and management, are being extended to developing countries It is this pervasive and versatile feature of electronics applications that needs to be stressed in relation to the impact of this sector. It must also be emphasized that electronics is a continuing growth industry, with new technological developments being constantly evolved, including in electronics publishing, computer graphics, laptop computers and an enormous range of new products and applications, and is very far from reaching a level of saturation, either in terms of technological developments or in the demand for its ever-widening range of products.

There has been rapid penetration of electronics and information technologies in industrialized countries. It is estimated by the Organization for Economic Co-operation and Development (OECD) that, in the OECD countries, the internal demand for such technologies registered growth in real terms of 6 per cent annually during 1975-1985. 8/ The penetration of such techniques in industry is reflected in the demand for such technologies as a proportion of gross fixed capital formation, as seen in Table IV.2.

Low energy and material requirements: An important feature of electronics production is that it is neither energy-intensive nor material-intensive and is a relatively "clean" industry from the viewpoint of environmental damage and pollution. Though uninterrupted electric power is an essential prerequisite, the power requirements are not particularly high. The requirements of raw materials are also not specially large, but the materials must be extremely pure. The availability of components, particularly semiconductors, is undoubtedly an essential element and needs to be planned as a critical input.

Knowledge-intensity and change: Electronics development is primarily knowledge-intensive. While research intensity is high, particularly at higher ends of the technological spectrum and for innovative developments, the principal feature lies in the innovative application of knowledge to various situations and requirements. A large proportion of technological developments in this field has been achieved through small research-intensive organizations and enterprises which have developed innovative products and applications in different fields. At the same time, overall research costs in this field are very high and major transnational corporations (TNCs) in this sector, such as IBM, AT&T, Hitachi and Siemens each spend billions of dollars annually on research and development, which is necessary to maintain technological leadership in this rapidly-changing sector. Research and development has generally been directed both towards major innovations and to proprietary products and designs, though incremental innovations have also been very successful, particularly in Japan and in other countries in South-East Asia in more recent years. The nature of the electronics industry, however, makes it susceptible to rapid technological changes and consequently to speedy obsolescence.

Global operations and location: Since electronics products, including most hardware, peripheral equipment, software and other elements are easily transportable, the electronics industry needs to be viewed on a global and international basis. 9/ Electronics has also often been characterised as a foot-loose industry, moving from one location to another to avail of particular factor advantages. The manufacture and assembly of electronic components in South-East Asia and other developing countries was a typical example of the industry taking advantage of cheap labour in these countries, till such time as greater automation reduced such advantage. Changes in the geographic location of production have been taking place at four diferent levels: 10/ (a) locational shifts among the major industrialized countries, (b) locational shifts from the centre to the periphery within industrialized economies, (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, Philippines, Sri Lanaka and the Caribbean. Japanese and West European firms are investing in the United States because it continues to be an expanding and attractive market, and because protectionist moves are inducing foreign firms to locate in the United States 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 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. Major future markets are also emerging among South-East Asian (ASEAN) nations, the Gulf area, Brazil, China and India. Though automated production methods make greater production possible in high-wage countries, being located close to markets still has major advantages and pressures are building towards vertical integration within the electronics industry. Thus, countries with both an electronics production industry and major user sectors have potentially promising markets.

Technology market in electronics

With increasing internationalization of the electronics industry and the rapid pace of innovative developments, the technology market is increasingly marked by alternative technologies and sources. The market for electronics technology has undergone considerable change since the 1960s and early 1970s when certain corporations had a predominant role in computers and related electronics development. 11/ Transnational corporations have played a dominant role in developing new technologies for communications, such as AT&T, Alcatel, Siemens and Ericsson, and for consumer and industrial electronics and other applications. Nevertheless, in recent years, a large number of new entrants have come into the field, particularly after the advent of micro-computers, and can provide technology and know-how for a growing range of electronics products and components. This development has taken place, partly because of extensive technology licensing, particularly by United States corporations to Japanese companies as also to certain corporations in Western Europe during the 1960s and early 1970s, particularly in computers, semiconductors and communications technologies. New technological applications and products were also developed by a large number of enterprises, which were often small but have grown rapidly in recent years. This is also true of software development, particularly in the United States. Replication and packaging of "electronic kits" for assembly of various electronic products, including for desk-top computers and peripheral equipment, has also developed fairly extensively in certain South-East Asian countries, particularly the Republic of Korea and the Taiwan Province of China. At the same time, there is also a high degree of product differentiation and similar products may be substantially differentiated in value because of particular brand names.

The spectacular growth of electronics has resulted in major problems relating to intellectual property rights. Patent legislation in several countries has not taken adequate account of the rapid developments in the electronics sector. 12/ In several countries, copyrights on software are not recognized and the same software is available at much lower prices. There is considerable divergence of views between industrialized and developing countries on the nature and application of intellectual property legislation in this sector. These aspects can have an important effect on technology transfer negotiations and contracts in this field.

Special mention needs to be made regarding the issue of legal protection of lay-out designs of integrated circuits. 13/ The industry of semiconductors is a leading sector because of its widespread economic impact, including defence, computers, telecommunications, consumer electronics and other segments of the growing market for semiconductor-based products. Most developed countries have enacted specific legislation, or are in the process of doing so, for the protection of lay-out designs of integrated circuits. The United States was the first country to adopt, in November 1984, a special law for the protection of "mask works" (the "Semiconductor Chip Protection Act" (SCPA)). The SCPA introduced a special title of legal protection for "mask works" fixed in a semiconductor chip product. The regulation adopted in other countries, as well as the WIPO Treaty, however, avoided the use of the "mask work" terminology, in view of later technological changes. During the mid-1980s, Japan and several West European countries adopted legislation to protect lay-out designs of integrated circuits. The initial superiority of United States firms in semiconductors was, however, seriously eroded in the 1980s. In 1975, the United States share was virtually 100 per cent. In 1984, when the SCPA was approved, such participation had fallen to about 60 per cent. It was further reduced to 42 per cent in 1988, when already six out of the ten major open-market producers of semiconductors were Japanese. In 1986, the United States concluded a "chip pact" with Japan trying, among other things, to monitor and maintain at certain levels export prices of chips. The integrated circuits protection is a remarkable example in the development of international economic law and shows how technological and political power may determine regulations for a very specific issue and on the basis of almost completely new standards.

While the rate of growth of various segments of electronics production will continue to be very high in the coming years, the degree of competition in the sector is also expected to increase considerably. Investments have to be carefully assessed in terms of the convergent segments to be concentrated on, recognizing that continuing research and adaptation alone would enable production enterprises to adjust to rapidly changing technologies and conditions of production. At the same time, technology in most subsectors of electronics, particularly those in which most developing countries would be initially interested, can be acquired from alternative sources; joint ventures and licensing are becoming increasingly common in a number of developing countries. With respect to advanced electronics technologies, however, considerable restrictions may be faced, particularly from the United States and other industrialized countries. The negotiation of technology agreements and contractual conditions for technology transfer may also be more difficult in the case of certain electronics and informatics technologies than in more traditional production.

Production and trends

The production of electronics products and equipment has expanded enormously during the 1980s in the USA, Japan and Western Europe, which cover 80-90 per cent of global production.

It will be seen from Table IV.3 that, during this period, production of consumer electronics has tended to decline in the USA and Western Europe and has increased substantially in Japan. The production of computers and components has risen significantly both in the USA and Japan and, at a lesser pace, in Western Europe. During 1986-1987, similar trends have continued, with the added factor of substantially-increased production of consumer electronics and computers and components in certain South-East Asian economies, particularly the Republic of Korea, Hong Kong, Singapore and the Taiwan Province of China. While production of consumer electronics and computers and components has also risen substantially in certain other developing countries such as Argentina, Brazil, India and Mexico, the proportion of their production to global output in these subsectors continues to be relatively small. Exports of electronics products rose to about $124.8 billion by 1985, of which major exports were from Japan ($36.2 billion) and United States ($26.4 billion). Exports from Taiwan Province of China, Republic of Korea, Hong Kong aned Singapore, however, expanded rapidly by the mid-1980s and rose to $14.6 billion in 1985 constituting over 70 per cent of exports of such products from developing countries. 14/

The pattern of growth in the informatics and electronics sector is likely to continue along the above lines during the early 1990s. With increasingly sophisticated applications, the proportion of electronics output in industrialized economies is likely to increase significantly in the areas of defence, industrial applications, communications and data processing. Demand for consumer electronics will continue to grow, with innovative developments in video and audio equipment, though the pace of growth in industrialized economies is likely to be slower than in the past. This will be in contrast to developing countries, where demand for consumer electronics will continue to increase rapidly in the next few years. Production of consumer electronics is also likely to expand considerably in a number of developing countries. It is, however, with respect to other electronics applications, particularly data processing, communications and industrial applications, besides applications in agriculture, macro-planning, energy planning and the like, that special attention may need to be given in developing countries.

With rapid expansion of the informatics sector and data processing, the various categories of computers, which comprised $160 billion of business in 1987-1988, are expected to experience further rapid global growth in the coming years. In micro-computers, this may be as high as 40-60 per cent, while the rate of growth for mainframes is likely to be slower. Personal computers already account for 40 per cent of the US market and 30 per cent in Europe, and are finding versatile applications in office operations, particularly as "office-work-stations". Software packaging for computers has also become a very fast-growing industry and is expected to exceed $50 billion by 1989-1990. 15/ In communications, the growth rate is expected to be around 15.8 per cent and value of production is expected to reach a level of $30 billion by 1989-1990. Of this, customer-premises equipment would account for around 14.5 per cent, with telephone and data work stations registering fastest growth with a global market estimated at $83 billion by 1987. Local area networks have also become important, in order to link micro-computers used in business. The other major items of growth include transmission equipment; data communication equipment; switching equipment; and cellular radio communications, which is growing rapidly.

Subsectoral growth pattern

Despite the growing convergence of electronics and information technologies it would be useful to review the major growth trends and prospects for local production in developing countries, in principal user sectors, recognizing, however, that there is considerable interface and overlapping not only in the use of equipment and interchangeable components but also in the various systems utilized in different fields.

Consumer electronics: This subsector, which includes high-fidelity audio; FM radio; television receivers; video casette recorders; and a growing list of products, is likely to be of most immediate interest to several developing countries in terms of growing demand and potential for local production. Technologically, the subsector ranges from the simple to the complex, particularly with recent developments in sound systems, video disks, laser disks, new forms of video games, and home control systems of varying degrees of sophistication. Developments in the consumer electronics sector provide some good examples of trends common throughout the electronics complex, particularly the tremendous proliferation of new products based on microelectronics. Growing demand for these new products has stimulated the resurgence of an already mature industry. United States sales for all consumer electronics products were $16.1 billion in 1982, $20.1 billion in 1983 and $22.7 billion in 1984. The consumer electronics industry, however, is now dominated by Japanese manufacturers.

In this field, there is likely to be a proliferation of technically minor innovations which are guided by newly created market opportunities where marketing strategies will be determinant. Amongst such examples are digital photography to be produced on paper by a printer. However, the principal trend in mass consumer electronics in the 1990s will be the development of high-definition television. It should also be possible for certain television broadcasts to reach nearly half of the inhabitants of the planet by the year 2000, almost simultaenously. A major problem to be resolved will be standardization as this would ensure the global character of this technological evolution. 16/

The components and materials for consumer electronics include passive components such as inductors, resistors, coils, capacitors, etc. and those which are active, such as tubes and transistors. The production of high-quality components, which can be undertaken in a number of developing countries, is vital for the success of the consumer electronics industry. The production of semiconductors, which require expensive etching, bonding and packaging facilities, may also need to be undertaken with a beginning being made with resistors and capacitors, which could be taken up for large-volume production. Simple types of printed circuit boards can also be produced. At a later stage, professional-grade items may be considered if the volume of demand justifies the large investments required for this purpose.

Computers: Perhaps no other branch of electronics has grown so rapidly in recent years as computers. Apart from the hardware comprising the central processing unit (CPU) and peripherals, software packages have become of vital importance to extend and expand the application of computers in a wide variety of situations. Computers are generally categorized under mainframe computers, minicomputers and microcomputers. Microcomputers constitute the fastest growth area in computers and the demand for microcomputers is expected to exceed $25 billion by 1989-1990, with the market for minicomputers being around $28 billion. The micro field is dominated by personal computers using 8 and 16 bits, together with small business computers with more bits and storage capability.

Data processing capacity and consequent demand for computers has grown extremely rapidly. Table IV.4 shows the production increase and the rise of computer stocks worldwide between 1977 and 1987. The even more rapid growth of micro- and minicomputers has been a significant development in the computer industry. These systems owe their development to improvements in components, making the 32-bit microcomputers common tools on working desks equal or superior in capability to the mainframes of the 1960s and far more convenient and user-friendly. The OECD earlier estimated that by 1987, the market in value terms for personal computers (costing less than $10,000 in 1984 dollars) will be greater than that for all other computers. 17/

Software constitutes the crucial factor in all applications of information technologies. 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 United States 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. 18/ Software is becoming an increasingly indispensable part of the package and hardware-software packages are being frequently marketed as a single product. The growth in demand for software programmes has transformed the software industry from sales of $2.7 billion in 1981 to over $10 billion by 1984 and growing rapidly in subsequent years. Several software companies have become major corporations. Thousands of new companies have entered this growing market. The world market for software is expected to increase by 30 per cent annually and could reach $150 billion during the early 1990s. Till the mid-1980s, most software companies concentrated on a particular niche, ranging from applications software to utility software and systems control software. These distinctions are blurring. Hardware manufacturers are strengthening their own applications software or having joint ventures with software producers. Software houses are extending to different fields. Publishers are licensing programmes and organizing sales through their distribution networks. All this activity has resulted in an increase in mergers and acquisitions and, in 1983 alone there were 146 acquisitions in the United States, valued at more than $1 billion. A degree of restructuring of the software industry can be expected. Intense competition is expected, particularly in applications software and database management programmes. The new competition in software may lead to price reductions and also increased involvement in software. Major innovative developments in software can be expected during the 1990s and more than 60 per cent of working time on electronics development is expected to be spent on software, including computer-aided software engineering tools.

Communications: Developments in telecommunications and their impact have been dealt with in the previous chapter. Communications, however, includes both telecommunications and other facilities for two-way communications including telephone, facsimile, telex, mobile radio, etc., as well as broadcasting of both sound and video. Closed circuit and cable television systems are also expanding coverage of their services just as new techniques such as citizen band radio, cellular radio and local area networks are increasing the capabilities of communications systems. Fibre optics, which provides new means of transmission, and wide band communications are increasingly being used to carry simultaneous single-voice circuits. Satellite communications technology has also developed into a powerful medium with considerable potential for flexibility, processing, switching and growth. Several countries, such as Canada, India, Indonesia, Japan, the Soviet Union, and the United States and others operate domestic satellite systems for communications and TV services. New developments in communications capability such as videotext, electronic mart, tele-conferencing and Community Antenna TV (CATV) are leading to automated offices and home office facilities. Electronic publishing and video data are likely to significantly replace the conventional media of books, journals and newspapers with customers obtaining information on demand from central data sources. Viewdata public service is now available in several industrial economies, while agricultural information systems have been widely extended in the United States and several other countries. Technological advances in communications have been linked to their digitization and based on the fact that the different types of equipment used have become information processing machines, directed towards specific applications and for which improvements in performance depends on that of the integrated circuits. The major development of the 1990s is likely to be the installation and refinement of global networks which carry not just speech but also information and data at high speed, including written texts, images and sounds and even animated images with sound. Telecommunications services with a wider band than those of the existing telephone networks will also be offered, during the 1990s. The services offered will be initially of the first generation Integrated Services Digital Network (ISDN) type, for which initial international standardization is in hand. 19/ New applications in communications will also undoubtedly be extended in a large number of developing countries, including rural regions in the near future.

Industrial applications: As discussed in the previous chapter, this is a vast and growing field because of the immense potential of electronics and informatics to control and monitor complex systems and to prepare designs and conduct integrated production operations through automated equipment in various sectors. These can range from textiles and clothing, where CAD-CAM has already been introduced in several developing countries, to the manufacture of automated equipment, especially numerically-controlled machine tools, which has also been undertaken in certain countries such as Argentina, Brazil and India. Work stations, industrial control systems and instrumentation also comprise critical equipment for such applications. Most such equipment and systems have varying degrees of application in developing countries and local production and developments have to be planned in relation to national factor endowments and technological capability.

One of the most critical elements in industrial applications is development of integrated circuits. The semiconductor industry was 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 accounted for approximately $24 billion. While the United States continued to have a lead up to the mid-1980s, Japan has rapidly gained competitive advantage and is now increasingly dominant. Most European chip products are outside the mainstream chip industry and are produced largly for specialized markets. With the exception of Philips, all top ten chip producers are Japanese and United States firms; the five next largest European companies are all markedly smaller than the five largest U.S. and Japanese firms. 20/

Instrumentation is the building blocks of the control systems and ranges from simple measuring and test instruments, such as multi-meters, to highly-complex instrumentation to determine and control various parameters in industrial operations. Testing and measuring instruments also constitute an important sub-sector. These are of varying degrees of sophistication, from simple oscilloscope to frequency control equipment, signal generators, logic analyzers and automated test equipment.

Medical electronics: An area of growing interest is that of medical electronic equipment which is now being increasingly utilised for diagnosis, therapy, patient monitoring and clinical analysis. The range of such equipment is fairly wide, from relatively simple instrumentation to highly complex systems. New techniques include the use of lasers for opthalmology, plastic surgery, cancer treatment, etc. Ultrasound is utilized widely for diagnostic areas such as blood flow measurements, ultra sound imaging of heart valves and various other applications, including electro-encephalography and diagnosis. Nuclear magnetic resonance scanning is a newly emerging area, and is utilized in CAT-scan studies of brain and body tissues etc. Microwaves are utilized in diathermy as well as for location of cancer. Modelling and signal processing constitutes an important tool for thorough understanding of physiological phenomena. The extent to which medical electronics equipment can be manufactured in developing countries will vary with the level of electronics development and technological capability but the range of applications will undoubtedly increase rapidly in coming years.

Defence and aerospace: The defence sector requires very specialised electronics items including radar, navigational aids, communications for defence, marine and underwater electronics and specialised military equipment for aerospace, land and naval operations. Defence electronics has been a major source of technological developments in electronics in the United States and in several West European countries because of the massive fund allocations provided for defence-oriented research. Most countries have defence programmes which are increasingly dependent on electronically-controlled equipment. Not many developing countries may need to design such equipment, but several of these countries will need to develop maintenance and repair capabilities to keep such equipment in operational order and to make simple spares.

Other subsectoral applications: The above account only exemplifies some of the varied applications of electronics in certain selected sectors. Such applications, however, are increasing every day and extend to most fields of economic activity.

Since the 1980s, the electronics industry has been subjected to considerable pressure and tension caused by continuing technological evolution. Companies involved in this field have had to review their strategic options constantly. Every branch of electronics has been subject to this process of restructuring and varying degrees of consolidation. 21/ A major feature has been the growing competition from, and even dominance by, Japanese companies. Public authorities in the United States and in Western Europe have sought to deal with this question by various means, including joint research, use of customs tariff and quantitative restructuring, but have achieved little success. This competition will continue and may increasingly intensify in the 1990s.

For developing countries, electronics and information technologies provide great challenge and opportunity. The growing markets of these countries have to be served. At the same time, labour costs continue to be a key factor despite developments in automation and robotics, and provided electronics technologies are absorbed and adequate pools of skills are developed there is great potential for use, application and adaptation of such technologies in a number of developing countries.

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Table IV. 1

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 IV.2

The share of investment in information technologies in gross fixed capital formation for a number of countries

(Percentage)

	1984	1987
Germany, Federal Republic of	11.6	13.5
United States	14.6	18.1
France	9.0	9.7
Italy	8.8	10.6
Japan	6.9	8.3
United Kingdom	15.0	16.7

Source: OECD, Science and Technology Policy Outlook (Paris, 1988), pp. 105-106 (of the French text).

Table IV. 3

Electronics production in United States, Japan and Western Europe, 1980 and 1985

(Millions of US dollars)

	United States		Japan		Western Europe	
	1980	1985	1980	1985	1980	1985
1) Consumer electronics	6,066	5,970	18,704	32,652	13,338	10,399
2) Computers and components	51,700	85,500	24,447	62,804	26,397	33,100
3) Factory automation	13,619	20,570	3,430	5,195	10,331	9,885
4) Communications and telecommunications	25,983	43,780	9,1209	19,937	24,100	23,600
5) Automobile electronics	3,630	5,520	2,942	4,656	5,284	4,557
6) Medical electronics	2,709	5,130	931	1,269	2,922	3,086
TOTAL (Approx.)	103,826	167,450	59,653	126,413	82,450	84,720

Source: Battelle Institute, based on national statistics.

Table IV.4

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.

CHAPTER V

THE INFORMATICS INDUSTRY IN SELECTED DEVELOPING COUNTRIES

There have been significant developments in electronics and informatics in several developing countries. The initial pattern of growth has primarily been in consumer electronics where increased demand and usage has been accompanied by the development of local production capability, often through TNC subsidiaries, in several countries. In the last decade, however, there has also been considerable growth in the usage of computers, particularly microcomputers, for a variety of applications, together with the use of communications satellites and other electronic equipment. The initial resistance to computers and data-processing equipment as aggravating local employment, which was a feature in several developing countries, has gradually given way to recognition and acceptance that computers and related equipment can be utilized as vital tools for economic activities and for developing international competitive capability in the present era of technological change.

The most rapid development in usage and application of electronics and information technologies has taken place in certain countries in South-East Asia, especially in the Republic of Korea, Hong Kong, Singapore and the Taiwan Province of China and also to a considerable extent in Malaysia, the Philippines and Thailand. These countries, which have had considerable initial inflow of foreign direct investment and technology, mainly in offshore electronics assembly and production of components, have developed substantial capability in production of electronics products and equipment. Not only are electronics products extensively utilized in homes and offices but increasingly in computer-aided designs and production operations in several fields. Microcomputer production increased in the Republic of Korea at 90 per cent annual growth rate from 1983 to 1987. By 1987, the country had also captured 9 per cent of the global market for certain memory chips (256K-DRAMs). 1/ The Republic of Korea and the Taiwan Province have emerged as major exporters of microcomputers, components and a wide range of consumer electronics products. Singapore has become a major supplier of computer peripherals and parts. There has also been considerable growth of computer usage and applications in some of the large developing countries, including Argentina, Brazil, China, India, Indonesia, Mexico and Pakistan, together with production of consumer elecronics and other electronic products. Among these countries, the development of microelectronics and informatics has been the highest in Brazil. In India, special emphasis has been given to microcomputer production and to software development, especially for exports. 2/ There has also been growth of computer usage in several middle-size developing countries in Latin America, Asia and North Africa, including oil-producing countries, with the level of technological development differing from country to country. In most other developing countries, however, there has been relatively little development of informatics, particularly in terms of local production and technological absorption.

The range of new informatics applications in several developing countries has become fairly extensive. Apart from rapid increase of computers, word processors and facsimile equipment in offices, electronics technologies are increasingly being utilized in finance, banking and trading operations, as also in factory management and in design and manufacture of garments, footwear and several other industrial products. Microelectronic applications have also been tested and applied in some developing countries for demographic surveys; energy planning; public health; agricultural operations, including surveys and remote sensing; forestry, irrigation; food storage; animal husbandry and animal feed; weather forecasting and meteorology; and other activities linked to agriculture. 3/ At the same time, with the exception of certain countries in South-East Asia, and some of the large developing countries, the growth of local production and technological capability in informatics has been fairly limited. There have been major constraints in usage and local production of computers and related software. These arise both from infrastructure constraints such as inadequate and irregular power supply and inadequate communications facilities and from severe shortage of trained personnel, particularly programmers; limited availability of hardware, including repair and maintenance facilities; little software capability and scarcity of packaged sector-specific software of direct relevance in particular country situations. There is, however, growing knowledge of the implications and potential of electronics applications and production, and policies and programmes are increasingly being focused on various aspects of such developments.

The extent of technology transfer to developing countries in informatics has been relatively limited, except for production of consumer electronics. In some countries, particularly Brazil and Mexico, TNC subsidiaries have also undertaken manufacture of microcomputers and peripheral equipment, besides telephone and communications equipment. The sales operations of companies like IBM have undoubtedly extended the use of computers, both mainframe and desktop, in a number of developing countries but, apart from offshore production of electronic components, there has been relatively little development of production or systems capability till the 1970s, when certain developing countries, such as Brazil and India, embarked on major indigenous development programmes, while several South-East Asian countries developed export capability not only in consumer electronics but for a wide range of peripheral equipment and components.

It is important to emphasize the major, even spectacular, developments in production and exports of electronic products from Hong Kong, Singapore, the Republic of Korea and the Taiwan Province of China, as also the major increase in computer products through nationally-owned companies in Brazil and, to a lesser extent, in Argentina, India and Mexico. In the South-East Asian economies, offshore production of electronics production by TNCs undoubtedly triggered the pace of growth, but export-oriented production of electronics and informatics products now largely rests with national companies, including major conglomerates in the Republic of Korea and nationally-owned enterprises in other countries. The advantage of cheap labour in South-East Asian countries, however, earlier led to the rapid growth of offshore production and assembly of components through TNC subsidiaries in Hong Kong, Republic of Korea, Singapore, the Taiwan Province of China, and Malaysia, and other countries to a lesser extent. During the late 1960s and early 1970s, several United States companies, including Fairchild, National Semiconductors, Motorola, Texas Instruments, INTEL, Mostek, RCA and others, as also several Japanese companies, including NEC, Hitachi and Toshiba, and European companies, such as Philips and Siemens, set up facilities for electronic component manufacture, including testing facilities in some cases. 4/ The volume of imports of electronic components, including integrated circuits, transistors, thermionic valves and tubes, etc. to OECD countries rose to over $3000 million by 1980. During the 1980s, with greater automation in electronics production operations, however, the trend towards offshore production of components has declined. At the same time, several joint ventures and licensing arrangements have been entered into for production of desk-top computers and peripheral equipment besides consumer electronics in several countries, including Brazil, India, the Republic of Korea, Singapore, Hong Kong and Taiwan Province of China. 5/

The banking sector and financial institutions including those involved in financing of exports, in most of these countries, have played an important role and been supportive of local initiatives and entry in electronics production. An effective framework of government policies has also been a crucial element in these countries in establishing a strong infrastructure for the development of electronics production and in enhancing exports.

The potential for developing endogenous capability in microelectronics and informatics can be better assessed in the light of experience of selected developing countries, with respect to production capacities, industrial structure, exports and the role of governments in these countries. These countries include Brazil, India and Mexico from among the larger countries and the Republic of Korea, Malaysia and Singapore from among the smaller, export-oriented economies of South-East Asia. While policies in these countries differed considerably, the levels of development achieved were, in large measure, due to supportive national policies combined with aggressive industrial initiative on the part of local industrial groups and enterprises.

Production capacities: The extent of informatics and components production and their relative importance in local electronics sectors varies significantly among selected developing countries. As indicated in Table V.1, Singapore and Brazil, followed by the Republic of Korea, are the largest producers of informatics products. In the manufacture and assembly of semiconductors, the Republic of Korea is the most advanced developing country. The size of informatics and components production in these countries is also significant in international terms as may be seen from Table V.2. Singapore and Brazil rank among the ten major producer countries, while the Republic of Korea ranks twelfth. However, Singapore and the Republic of Korea basically produce for export markets, while Brazil's exports of informatics products are only a minor part of total production. In overall terms, as a percentage of world informatics production, the participation of the developing countries is still small. Their share is considerably higher, however, in the field of components, with the two Asian countries jointly accounting for over 12 per cent of world production of active components and around 5 per cent of passive components. The Asian countries are, in terms of output and trade balance, well ahead of Latin American countries. If in addition to the Republic of Korea, Singapore, India and Malaysia, other Asian countries such as Hong Kong, Taiwan Province of China, Indonesia, Philippines and Thailand, are taken into account, the total output in informatics products of components would be $4.2 billion and more than $12 billion in value of components. In Latin America, only Brazil has a comparable level of production. The two largest Asian economies, India and China, have a minor role in informatics production in international terms. India's annual production of microcomputers, for instance, was only about 40,000 units in 1988, while a similar level of production has been reported for China. 6/ The production of informatics products in selected developing countries is given in Table V.3.

Production patterns: Important differences can be identified in the levels of domestic and technological content. In most of these countries, the development of the informatics industry has been based on assembly techniques and low domestic value-added. However, certain countries are making considerable efforts to develop local sourcing of certain parts and components. New developments are also taking place in some developing countries towards greater production integration, even in technologically complex areas such as semiconductors. In India, imports of microprocessors for microcomputer production is permitted. In Latin American countries, particularly Argentina, Brazil and Mexico, while the local electronics industry is based mainly on assembly operations, the national informatics policies have sought to use the development of computers and peripherals to achieve more integrated local production. In Brazil and Argentina, consumer electronics production is concentrated to a large extent in free trade zones (Manaus and Tierra del Fuego, respectively), where imported parts and components are assembled. In the case of Argentina, in particular, the existence of such a zone has been a disincentive for the development of a more integrated electronics industry. The Mexican case presents similar features due to the activities of **maquiladoras** (assembly firms). The Brazilian policy seems to have attained its main goal of substantial increase in the use of local parts and components in informatics production since 1981. In Mexico, the goals set by the Government in 1981 for local integration were relaxed soon after, in order to ensure competitive prices and to promote exports.

In the case of semiconductor production, the Republic of Korea has made efforts to extend local production to all stages of manufacture. In 1974, Samsung Semiconductors and Telecommunications Co. Ltd., started its first wafer production. It was followed in 1979 by Goldstar Semiconductors Ltd. Currently, there are five wafer fabricators in the Republic of Korea, with an estimated output of $550 million in 1987. 7/ The semiconductor industry is also achieving backward integration in the form of wafer fabrication in Singapore and Malaysia. In Singapore, recent developments are transforming the industry from the production of simple bipolar integrated circuits to more sophisticated products. SGS/ATES and Hewlett Packard have invested in diffusion units for integrated circuits for mass consumer products and for gallium arsenide circuits, respectively. ATT has invested in a design unit, Unizon (Japan), in a production line for discrete semiconductors and integrated circuits, while a joint venture (involving National Semiconductors, Sierra Semiconductors and Singapore Technology Corporation) has been set up to establish a $50 million unit for CMOS integrated circuits. 8/ In the case of Malaysia, Motorola will produce discrete transistors and INTEL has received government authorization to set up a major $100 million microprocessor manufacturing unit.

The mere assembly, on the one hand, and a high degree of integration of local parts and components, on the other, are alternative approaches. Assembly generally permits production at competitive prices and hence, facilitates local diffusion and use of the technology as well as exports. The impact of this approach on employment, labour skills and industrial and technological absorption, however, is generally limited. In contrast, the development of local sourcing requires a certain de-linking from the international market, but may assure the creation of a domestically-integrated industry and the upgrading of technological capabilities. Production trends in informatics in developing countries often reflects the ambivalence between these two approaches.

Industrial structure

With respect to industrial structure, powerful industrial conglomerates dominate the electronics industry in the Republic of Korea. In particular, Samsung, Goldstar, Hyundai and the Daewoo Group account for about 50 per cent of microcomputer production and for 100 per cent of semiconductor wafer fabrication. Their large financial resources, the learning process developed in consumer electronics, the setting up of an R&D infrastructure and the exploitation of economies of scale, are among major advantages for large conglomerates to operate in high-technology electronics. In India also, the electronics industry is largely centred around fairly large firms. In microcomputers, four major producers (HCL, Sterling, Wipro and Eiko) dominate the market. In mainframes and minicomputers, ECIL and International Computers Ltd. (ICL-India) are the principal manufacturers. The top ten manufacturers account for 80 per cent of the output of computers, while the remaining 20 per cent is accounted for by 70 small units mostly engaged in assembly activities. Two major differences between the Indian and the South Korean experience are that, firstly, in India, some of the major enterprises in the field are public-owned, though there is growing participation of foreign and national private firms, including smaller-size enterprises, and secondly that Indian firms mainly specialize in the manufacture of certain types of equipment, and do not cover such a wide range of products as the South Korean conglomerates. 9/ The large integrated corporations may be better positioned to finance the high investments required to compete internationally and to enter into new and capital-intensive fields, such as semiconductor production.

The computer industry in Latin American countries has generally followed a pattern of specialization. Small and medium enterprises are predominant in Argentina, Mexico and Venezuela. In Argentina, the average number of employees per firm was 110 persons in 1983. The 11 firms that obtained promotional incentives for computer production in the country planned a total investment of about $40 million and a total employment of 3,700 persons by 1992. 10/ In Mexico, the expansion of the domestic market allowed the emergence of about 100 producers of micro- and minicomputers and peripherals, with job creation of 6,000 by 1987. Seventy-one per cent of the enterprises operate in the field of microcomputers and peripherals. Due to low levels of automation and equipment investment, however, they only account for 23 per cent of total fixed assets. 11/ In the case of Venezuela, over 100 enterprises participate in the growing market for professional electronics goods (telecommunications, industrial controls, data processing and components). In Brazil, more than 200 firms produced computers and peripherals in 1987. A number of relatively large firms have emerged as a result of protectionist policies. While IBM and Unisys continue to be major producers, both in terms of aggregate sales and employment, in the field of microcomputers, minicomputers and peripherals, five national firms had each more than 1,000 employees in 1985. The growing competition that characterized these markets has led to a significant decline in the level of concentration since 1979. Out of the ten major national informatics firms, five (Itautec, Cobra, SID, Labo and Edisa) are directly or indirectly controlled by large financial institutions.

Internal and export markets: Two alternative models have developed. India, Argentina and Brazil have concentrated on production for the domestic market and import substitution has been a major objective. In contrast, the Republic of Korea, Singapore, Malaysia and, to some extent, Mexico, have opted for an export-oriented approach. Brazilian and Indian policies are good examples of the former approach. The exploitation of their large internal markets has been considered the basis for sectoral development. The Brazilian computer market exceeds US$ 3 billion annually 12/ and is clearly the biggest market in Latin America. The estimated value of computer systems sold in India was Rs. 2800 million in 1984. However, the potential growth of the market, as shown by the escalating sales of microcomputers, is still considerable. Notwithstanding the relatively small local Argentine computer market, the national policy designed in 1984 also emphasized development for the internal market as the first step in the building up of a national industry. Export requirements for the granting of promotional incentives were fairly low (about 7 per cent of production). In Argentina, as well as in Brazil, most exports in the informatics field are accounted for by TNCs, particularly IBM. On the other hand, in Singapore, more than 85 per cent of the country's electronic production is exported (60 per cent of it to the United States). Office equipment and informatics products, particularly computer peripherals, increased their share in total electronics exports from 6 per cent to 46 per cent between 1980 and 1987, while that of components fell from 43 per cent to 25 per cent. 13/ The role of TNCs in such exports has been considerable. In Malaysia, likewise, almost 90 per cent of electronics production, mostly controlled by foreign-owned industry, is exported. The largest part of such production (about 85 per cent) relates to semiconductors.

The role of the State: State intervention has been prominent, in particular, in the industrial strategies in informatics and semiconductors in India and Brazil. In addition to providing general policy framework and support, the State undertook production activities. In India, the public sector company ECIL, for example, manufactured computer systems ranging from 8-bit and 16-bit systems and is engaged in hardware design, software development, manufacturing, marketing and maintenance, including the 32-bit computer System 332 developed and manufactured indigenously. 14/ Two State-owned firms, Bharat Electronics Ltd. (BEL) and Semiconductor Complex Ltd. (SCL), produce integrated circuits in India. The BEL facility is vertically integrated in terms of CAD and mask production. In 1984, the company decided to manufacture microprocessors and memory chips using RCA technology. SCL has focused on the supply of modules and electronic circuit blocks for watches and clocks assembled in India, among other items. In the case of Brazil, the federal government enterprise for computer services SERPRO initiated the production of computer hardware in 1970. These production activities were later transferred to the State company COBRA which developed terminals and minicomputers for internal commercialization. On the basis of the COBRA 500 minicomputer launched in 1980, the enterprise became the leading computer firm in that segment in Brazil. In 1981, it produced nearly 50 per cent of all minicomputer installations and accounted for one third of total sales in the domestic market. 15/

In most other developing countries, foreign direct investments have been actively promoted and play a major role in the production of informatics products and semiconductors. In Malaysia, foreign-owned subsidiaries, mostly from the United States, account for the largest share of production, particularly in semiconductors. Singapore is particularly open to foreign industrial investments and 64 out of 104 firms in the field of components and 16 out of 25 in industrial electronics are of foreign origin. 16/

In India, the government policy aims at limiting the operations of foreign wholly-owned subsidiaries and requires the establishment of joint ventures with local partners. Recently, a number of joint ventures have been negotiated with Control Data Corporation, Digital Equipment Corporation, Data General and Olivetti for the manufacture of mainframes, super-minicomputers and other equipment. The informatics policy in Brazil has been structured on the principle of "market reservation" for local firms, and neither imports nor foreign direct investments are permitted in certain reserved segments of the market. These include minicomputers, microcomputers and peripherals. According to the Informatics Law No. 7232 of 1984, foreign participation in those areas is only permitted up to 30 per cent of the enterprise's capital, provided that effective control of its operation remains with the local partners.

In a third group of countries, the situation is not as well defined. In Argentina, the informatics policy established in 1984 promoted the establishment of joint ventures with foreign firms (Burrough and Bull associated, as a result, with private local firms). Although no formal decision rule was adopted, wholly-owned foreign subsidiaries were not considered suitable for local absorption and development of technology. In Mexico, the policy announced in 1981 was also based on the establishment of joint ventures. However, after long debate and in the context of a substantial change in the overall foreign investment policy, 100 per cent investment by IBM for microcomputer manufacture was accepted. In Venezuela, likewise, amendments to the foreign investments regulation have relaxed authorization procedures in the informatics field. In the case of the Republic of Korea, the Government has significantly intervened to regulate foreign direct investment and to set the conditions for the participation of foreign firms.

The various approaches followed reflect different perceptions of the advantages and disadvantages of the participation of TNCs. Countries concerned with building up indigenous industrial and technological capability have viewed such participation and control as a potential risk. The marketing power and technological superiority of TNCs can, in fact, create barriers to setting up new national enterprises, if these are forced to compete in an open market with the former. In some countries, such as Brazil, even the role of joint ventures between national partners and TNCs has been questioned. On the one hand, it is feared that the asymmetry of effective commercial, financial and technological power between the partners could lead sooner or later to a subordinate role for the local party. On the other, in order to undertake a local learning process and attain self-reliance, it is necessary to fully involve national professionals and entrepreneurs. In contrast, other strategies have tried to rely on TNC production or marketing abilities, particularly for exports. In the case of Mexico, for example, it was clear that a significant trade-off existed beween the acceptance of foreign direct investments to promote exports and the establishment of reserved markets for national enterprises. In the Republic of Korea, instead, the relationships with TNCs primarily aim at taking advantage of the latter's marketing capabilities.

Technology transfer: The development of the informatics and semiconductor industries in developing countries has been based largely on the transfer of foreign technology through licences and similar arrangements. In semiconductors, assembly operations by TNCs in the Repbulic of Korea, Malaysia and other South-East Asian countries did not involve any significant transfer of know-how. Assembly utilizes technology almost exclusively embodied in imported capital goods and the assembly operator requires little technical training to reach peak efficiency. When the Republic of Korea and India initiated manufacturing activities in integrated circuits they were able to obtain licenses from foreign sources. In 1983, Samsung Semiconductors and Telecommunications Co. Ltd. made an agreement to introduce 16K static random access memory (SRAM) and 256K ROM from Sharp in Japan. In the same year, it established a firm in California for the purpose of technology absorption and design of circuits, and made an agreement with MICRON of the United States to produce 65K and 256K DRAMs. 17/ Goldstar Semiconductors Ltd. began to work on 8-bit microprocessors under license from Zilog in 1983, and on CMOS technology under an agreement with LSI Logic. The main sources of technology have been firms from the United States and, to a lesser extent, Japan. In India, Bharat Electronics Ltd. entered into a collaboration agreement on CMOS technologies with RCA. Semiconductors Complex Ltd. did the same with American Microsystems Inc. for LSI circuits. On the basis of imported technology, the recipient firms undertook a learning process which enabled them to envisage new technological steps. For instance, while Samsung Semiconductors and Telecommunications started production of 256K DRAMs on the basis of an imported design, it claimed to have developed the process itself. Indian Semiconductor Complex Ltd. developed in-house 3-micron CMOS and NMOS technology, although it had the option to obtain it under an agreement entered into with American Microsystems.

In most of the developing countries discussed above, namely, the Republic of Korea, India, Argentina, Malaysia, Mexico and Venezuela, transfer of technology agreements have been subject to prior authorization or registration. A process of liberalization, however, took place in the 1980s in most of these countries. It is only in Brazil that technology transfer policy has been maintained without substantial changes, though interpreted in liberal and pragmatic terms. In informatics, in particular, licensing has been viewed as a first step to obtaining the knowledge necessary to enter into new fields.

Research and development activities: It is difficult to assess the extent and composition of R&D activities undertaken in the countries under consideration. Not surprisingly, two of the countries with largest production in electronics, Brazil and the Republic of Korea, are the most relatively advanced in terms of R&D infrastructure at the public and private levels. In India also, there are a number of enterprises with considerable R&D activities. In Singapore, an important increase in R&D expenditures as a percentage of GDP has taken place during this decade from 0.6 per cent in 1985 to an estimated 1 per cent in 1988.

Software development: Overall, developing countries are largely dependent on hardware and software imports. The latter include mainly basic software, application tools and other types of packaged software. Some countries also import custom software, particularly for public administration projects. However, applications such as those for administrative and accountancy, are generally developed by local firms. In a few countries, particularly India, the development of basic software, including operating systems, has been envisaged by public and private enterpries. Locally developed software accounts for a minor part of the market in the Latin American countries. In Argentina, only 30 per cent of the market (in value) was covered by local production, while the level was about 40 per cent to 45 per cent in Mexico in 1987. For Brazil, a recent estimate indicates that only a quarter of the total market is provided for by local software producers 18/(in-house development excluded). In Venezuela, local software industry is also incipient and basically limited to the supply of application solution programmes. The situation in Asia does not substantially differ. Although 71 per cent of the Republic of Korea's software supply is accounted for by local firms, software imports increased at an annual rate of 101 per cent, between 1983 and 1985 and local suppliers have relatively low levels of specialization and technical capabilities.

Some countries, however, have made significant efforts to increase domestic software production and, particularly, to develop export potential. The best known example is India. As early as 1970, the Indian Government devised policy measures in order to expand software exports. In 1986, the policy was liberalized and some arrangements with TNCs (Burroughs, Texas Instrumets) began to produce significant results. In the financial year 1987-1988, exports of Rs.800 million were achieved. The establishment of "software technology parks" in India, with direct satellite link with companies in the United States is currently being promoted. Singapore also put into practice a policy for training centres and research projects in order to become a software exporter by 1990. Isolated cases of software exports have been identified in Argentina, Brazil, Venezuela and Mexico also, but the nature of the products involved and the economic dimension of the operations are relatively limited.

Software production is a promising field for many developing countries and it is relatively easy to exploit the growth potential of the software sector. Paradoxically, while several newly-industrializing countries have demonstrated their ability to successfully enter into segments of hardware production, the efforts made to establish software capabilities have not had equally significant results. Among the major obstacles faced by developing countries are the dimension of the domestic market, the present structure of local supply and the weakness of marketing capabilities. Estimates of market size in Latin American countries indicate about US$ 150 million for Argentina, and US$ 700 million for Brazil. The software market of the Republic of Korea was roughly estimated to be US$ 76 million in 1985, growing at an annual rate of about 52 per cent since 1983. The structure of local software supply in these countries usually indicates considerable fragmentation and the predominance of small enterprises. In the Republic of Korea, for example, about 1,000 firms have been identified, almost half of which have less than 15 employees. In Argentina, similarly, 82 per cent of more than 120 firms selling software have less than ten employees. In both cases, investments in equipment and software tools tend to be very low. Similar characteristics of software supply have been observed in Venezuela.

Human resources: The development of human resources is undoubtedly one of the most critical elements of any strategy for creating an industrial and technological base in informatics and microelectronics. The lack of qualified personnel for research and development, design and engineering activities, management and teaching (especially at the university level) represent a significant bottleneck in most developing countries. In the countries that have experienced rapid development in these fields, such as the Republic of Korea and Singapore, the shortage of available personnel emerges as an important limitation for future growth. In some other cases, as in Argentina, the training of professionals and technicians in electronics has clearly exceeded actual demand, due to the drastic reduction of production in the second half of the 1980s. The shortage of qualified personnel is considered a major problem, particularly in Asian countries. To reduce the gap, the role of universities in the training of scientists and engineers may need to be complemented by specific programmes. In India, for example, the gap between the availability and demand for skilled personnel to design, manufacture, apply, and maintain computers and develop software packages for using them, is estimated to rise to 80,000 by the end of the Seventh Five-Year Plan (1989-1990). As against this requirement, the proportion of professionals who have computer education/training from recognized institutions is estimated to have been about 5,000 in 1985-1986, while the number of professionals required to implement even the existing computer activities optimally is about 1200 annually. The authorities of the Republic of Korea have set a goal, for the year 2000, to increase the number of scientists and engineers from 11 to 30 per 10,000 of the population, a level comparable to that of Japan. Likewise, it plans to bring back 2,000 overseas trained scientists and engineers. Graduate and post-graduate training in the universities of the Republic of Korea has been expanding. The Government set up the Korea Science and Engineering Foundation and the Korea Research Foundation in order to promote and finance research in university laboratories.

Prospects and issues in developing countries 19/

The rapid development of the electronics sector is of vital interest to developing countries as it constitutes a critical phase of industrial and technological development. Such development is essential both from the viewpoint of creating new employment opportunities and of developing competitive skills and capability in a period of rapid technological change. It needs to be emphasized that electronics production often involves less capital investment than many other sectors. The number of jobs created through an investment of, say, $1 million would be higher in electronics than for most production sectors. The increased use and development of microelectronics and informatics in developing countries is also essential for overall technological development and capability to participate effectively in international markets. On the one hand, usage of computers and other equipment utilizing microelectronic devices needs to be gradually extended to various industrial and service sectors for greater efficiency, productivity and competitive capability in these fields. While the nature of application and usage may differ, in varying degrees, from that of industrialized countries, microelectronic applications cover a very wide range and have considerable potential for usage in all countries. On the other hand, production capability has also to be developed with respect to both hardware and software. The nature and extent of such developments will inevitably vary in different country situations but it is essential to develop a concerted strategy for production of software and such elements of hardware as may be feasible from a techno-economic viewpoint. Several developing countries should be able to develop international competitive capability, both with respect to software and for peripheral products and components for exports, apart from meeting internal requirements in different sectors. Capital goods production, which is increasingly being undertaken in many developing countries, should take new technological developments into full account. Production of machine tools and of mechanical, electrical and transport equipment should incorporate electronic components to ensure greater speed and accuracy and to keep pace with global developments in these fields, especially at the lower end of the technological spectrum.

With respect to increased usage of computers, modern telecommunications systems and automated equipment, there is also need for evaluation of such usage for industrial management and services; economic models and macro-planning; census and statistical operations and agricultural and industrial activities. There is also considerable scope for blending microelectronic applications in traditional sectors, particularly in agricultural operations such as for irrigation control, testing of moisture content, monitoring rainfall and weather conditions, food processing and storage, livestock development etc., and improving productivity in rural industries. There is also substantial potential for technology blending in several manufacturing fields and in various services. The use of CAD/CAM needs to be extended to various production sectors, particularly those with export potential. While the use of robotics and of flexible manufacturing sysems may be more gradual, numerically-controlled machine tools have increasingly to be utilized, and also produced in developing countries where machine tools are being manufactured. At the same time, because of the continuing and growing pressure for increasing employment opportunities, it would be necessary to determine both the appropriate usage of computers and automated equipment and the extent to which human labour should be replaced in particular sectors and provided with retraining and other facilities, besides alternative sources of employment. The new job opportunities created in the electronics sector would vary considerably. At one end, there would be need for skilled engineers, technicians and programmers, who would require technical degrees and specialized training. At the other end, the requirements would be primarily for semi-skilled personnel, who may require little training for a variety of jobs in electronics assembly and manufacture. Electronics production can also be undertaken on a relatively small-scale basis, with low investment and little infrastructure, except for electric power supply.

The determination of appropriate usage of electronic equipment is a key element of technology planning and assessment, which involves analysis of various objectives and priorities, as also choice of the electronics subsectors to be developed, ranging from consumer electronics to production of components and instrumentation and to production of personal computers, peripheral items and telecommunications equipment. The development of software and systems capability is also an important requirement. While computer usage and microelectronic applications must be increased in several fields and developed for data processing, storage and communications, this must be consistent with broader socio-economic goals. The major constraints in the development of infrastructure for hardware, software and systems capability must also be recognized and provided for. National policies in developing countries should, after taking account of such factors and constraints, determine specific norms and standards regarding computers, microelectronics and telecommunications equipment and components, and should define the desired pattern of growth for production of hardware, software and systems capability. This has to be periodically reviewed because of rapid obsolescence and technological change and the need not only to keep pace with new innovations and developments but to leap-frog such developments through technological adaptation.

There is undoubtedly considerable scope and potential for local manufacture of various electronics products and components in a number of developing countries, once the basic infrastructure, particularly human skills, can be developed, and suitable policy measures and incentives are defined. The shift to local production of more sophisticated parts and components may be more gradual in certain countries where the level of technological absorption may initially be low. However, provided the basic infrastructure of electric power and semi-skilled and trained human resources can be made available, the emphasis in most developing countries should be on the development of software capability on the one hand and production and assembly of a wide range of consumer electronics and industrial electronics products on the other.

The development of local software constitutes both an essential prerequisite and a major opportunity for several developing countries. With relatively cheap availability of technical personnel in several of these countries, there is considerable potential for development of applications software, both for local needs and for export markets in industrialized countries, where a major shortage of software programmers is expected in the 1990s. Software development may require, apart from basic training in computer programming at local institutions, foreign linkages in the form of joint ventures or subcontracting arrangements with foreign software companies. Several corporations in the United States and Western Europe, who are engaged in software development and applications, are exploring avenues for subcontracting software applications and development. This has become fairly common in India and other Asian countries. With the enormous growth of new software applications during the 1990s, several developing countries can develop a niche for specific fields of software development, with training and incentives oriented towards such development and with linkages and joint ventures with foreign software companies.

The development of electronics hardware, apart from consumer electronics, also presents significant potential for several developing countries. It should be possible to undertake local production of a wide range of industrial electronics products in these countries. These could include desk-top computers; disk drives; flexible magnetic disks; component boards; keyboard assembly; display assembly; scanners; printers; plotters and memory storage devices. Besides, a wide range of discrete components can be locally produced, such as diodes, ranging from small, signal diodes to diodes for special applications; transistors, including bipolar power and microwave transistors and thyristors; resistors; ferrites; condensers; relays; tubes; hybrid circuits, including photo-receiver or transmitter packages; and integrated and printed circuits, ranging from linear, monolithic integrated circuits to interface, and custom-integrated circuits. Audio components would include microphones, loudspeakers and amplifiers. In the communications subsector, local manufacture could be undertaken of telephone hand-sets, two-way communications systems and manual and automatic exchanges, in progressive stages. Various instruments can also be locally manufactured, ranging from simple multi-meters to complex control instruments used in industry, power systems and the like.

For many of these products, the initial investment is not unduly high in relation to overall investments in the electronics sector. Production processes tend to be similar, so that initial technological absorption could be rapidly extended to technological adaptation, except perhaps, at the higher ends of the technology spectrum. The acquisition of foreign technology should be possible as there are several alternative foreign sources from which such technologies can be secured, except for advanced technologies and products, whose exports may be restricted. It would, however, be useful to develop a comprehensive information base at national level on alternative sources of informatics technology and on terms and conditions of technology acquisition in the electronics sector.

Electronics production requires to be closely linked to growth in other sectors. The local machine-tool sector, for example, may need to provide various tools and equipment for the wide range of operations involved in electronics production. The equipment could extend from simple lathes and drilling and punching machines to complex milling or grinding equipment, or spark erosion machine or fine blanking to form and shape special parts. Facilities for electro-plating, engraving and spray painting are also necessary. An important aspect is that electronics, being critically technology-dependent, requires continuing contact with innovations and the generation of new electronics technologies. This can pose a problem in most developing countries. One alternative is to maintain continuing links with foreign technology suppliers, if technology is imported as it would be initially in most cases. In such cases also, it is necessary to ensure that the foreign partner or licensor continues to generate and develop new technologies. If not, alternative sources of new technologies will need to be explored. Apart from external technological links, it is important to ensure close linkages with local research institutions and centres. These may not normally relate to basic technological advances and breakthroughs but would be more related to operational programmes, which would increase productivity or programmes involving blending of technologies in traditional sectors and processes.

Notes and references

1/ This section is largely based on UNIDO, Technology Trends Series No. 9: Developments in the Field of Informatics in Selected Developing Countries, Carlos P. Correa (UNIDO consultant), UNIDO document IPCT.91, October 1989.

2/ ibid.

3/ Report of Ad Hoc Panel "Microcomputers and their Applications for Developing Countries", National Research Council, Westview Press, Boulder, Co., 1986.

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19/ This section is largely drawn from UNIDO Guide for Industrial Investment and Promotion in the Electronics Sector in Developing Countries, UNIDO document IPCT.78, July 1988.

Table V.1

Production of informatics goods and of electronics components in selected countries

(Millions of US dollars)

	Informatics	Components passive	Components active
India (1986)	185	308	155
Malaysia (1986)	69	160	1554
Republic of Korea (1986)	900	1294	1905
Singapore (1986)	1409	1298	1679
Argentina (1983)	64	n.a.	n.a.
Brazil (1986)	1400	892	418
México (1984)	250	n.a.	83*
Venezuela (1987)	100**	n.a.	n.a.

Source: For Asian countries and Brazil, calculations are made by GERDIC on the bases of Mackintosh Yearbook, Electronics Data 1987, Benn Electronics, Luton 1987, quoted in UNIDO, Estudio global sobre la electrónica mundial, ID/WG.478/2 (SPEC), 3.9.88. For Argentina and Mexico, Interamerican Development Bank, Progreso Económico y Social en América Latina, Informe 1988, Washington, 1988. For Venezuela, Fernando Martínez Móttola, "Electrónica e informática: alternativas para Venezuela", Integración Latinoamericana, INTAL, Buenos Aires, Nº 138, septiembre 1988.

* Available data do not discriminate between passive and active components.

n.a.: not available.

Table V.2

Major producers of informatics goods and of active components, 1986

	US$ million
United States	43.773
Japan	19.630
Fed.Rep.of Germany	8.742
United Kingdom	5.461
France	4.129
Italy	3.615
Singapore	1.409
Brazil	1.400
Netherlands	1.491
Canada	1.153
Ireland	1.003
Republic of Korea	900

Major producers of active components
(1986)

	US$ million
United States	14.900
Japan	12.770
South Korea	1.905
Singapore	1.679
Malaysia	1.544
Fed.Rep.of Germany	1.332
France	1.245
Phillipines	1.103
United Kingdom	1.013
Taiwan	941
Netherlands	572
Italy	484
Brazil	418

Source: Mackintosch Yearbook, *op.cit.* in Table 1.

Table V.3

Production of informatics goods and components as percentage of world prodution in selected countries, 1986

(Percentage)

	Informatics	Components passive	Components active
India	0.19	0.59	0.37
Malaysia	0.07	0.31	3.68
Republic of Korea	0.94	2.48	4.54
Singapore	1.47	2.49	4.00
Brazil	1.46	1.71	1.00

Source: Mackintosh Yearbook, op.cit. in table 1.

CHAPTER VI

BIOTECHNOLOGY

Biotechnology can be defined as the use of biological organisms or their constituents, such as cells and DNA, for the tranformation of inputs into commercial outputs 1/ and involves the conversion of various new materials into a variety of products through biological transformation. Traditional biotechnology has a long history, including activities such as fermentation of wine or soya and the brewing of beer. During the 1960s and 1970s, biotechnology was successfully utilized in the development of high-yielding varieties of crops and had a major impact on agricultrual developemnt.

From around the mid-1970s, however, the potential of biotechnology was considerably enhanced by major innovative developments in research. These included breakthroughs in recombinant DNA and in cell fusion, which enabled new combinations of genes or modifications in the functions of biological organisms. These and related technological developments have created a wide range of possibilities for the production of genetically- engineered materials and for bringing about changes in the genetic structure. The potential of such "new" biotechnology can be enormous and would extend not only to agriculture and livestock development but to various industrial sectors and processes, including pharmaceuticals, food industries, chemicals and other fields. The new biotechnology draws closely on a number of scientific disciplines, including molecular biology, chemistry, biochemical engineering, microbiology, cell biology, and informatics. The source of these scientific capabilities is to be found mainly in universities. It also necessitates the development of complementary capabilities to enable transformation of such scientific knowledge into production of new products and development of new processes on a commercial basis. Basic industrial infrastructure is also required, such as transportation facilities, electrical power supply, repair facilities, availability of laboratory technicians, foreign exchange for necessary inputs etc.

While biotech developments are mostly in various stages of advanced research and testing, several biotechnology-based products have already begun to be marketed. These include (a) Human health applications: A great deal of biotech research has been concentrated on human health applications, particularly for serious illnesses. Diagnostic kits developed from monoclonal antibodies were among the first products through biotech processes. In June 1986, the first therapeutic use of a monoclonal antibody for kidney transplants was approved in the United States. Several other products are in various stages of testing and approval. Other products produced through biotechnology include antibiotics, human insulin, human interferon, a vaccine against hepatitis and various products for immunotherapy.
(b) Sugar-substitute sweeteners: High-fructose corn syrup (HFCS) has been produced with the use of immobilized enzymes. Similarly, aspertame, a microbially-produced sweetener, is also being increasingly substituted for sugar. (c) Increasing productivity of vegetable oils: The production of palm oil has been increased by 30 per cent (oil yield per tree) as a result of the

cloning of the palm oil plant. (d) Bovine growth hormones (bGH): Milk productivity (output of milk per cow) is expected to be substantially increased through development of bovine growth hormones by genetic engineering. (e) Production of rare plants in industrialized countries which were produced only in developing countries. This is exemplified by the experience with the plant **shikonin**, which has medicinal properties and which was produced mainly in China and in the Republic of Korea. It is now being produced in bulk through tissue culture techniques in Japan by the Mitsui Group. 2/ Other examples include the development, through tissue culture in industrialized countries, of plants for pharmaceutical uses such as codeine and quinine and other plants having significant commercial demand. Genetic engineering is also being used to develop new plant varieties that are suited to the temperate climates of developed countries. One well-known example is the development of so-called ice-minus organisms. By changing the genetic structure of these organisms it is possible to facilitate production of tomatoes in temperate climates (f) Development and marketing of improved seed varieties: This is being rapidly extended for various crop varieties, with TNCs assuming a major role in development and marketing of such new varieties. (g) Livestock development: Vaccines are being developed for various livestock applications. A vaccine was developed to prevent pseudorabies in pigs. Considerable research is also taking place on cloning of animals.

Entry of new enterprises in biotechnology

Economies of scale in production do not normally constitute substantial barriers to the entry of firms in this field. Biotechnology is more knowledge-intensive than capital-intensive. There are nevertheless significant economies of scale in marketing and distribution. For this reason, new biotechnology firms frequently enter into agreements with larger companies for the marketing of their biotechnology-based products. The most critical requirement, however, is with resepct to research and technological skills. According to one estimate, a minimum of 25 PhDs are necessary to create a new biotechnology firm. While such a number may not be essential, it indicates the nature of the skills and applied research capability that is required. The financial requirements for starting a biotech enterprise may not be unduly high, depending on the area of concentation, but could extend to initial capital requirements of $10-20 million. 3/

Regulation of biotech application

It is important that the results and applications of biotechnology are appropriately regulated. In fact, in most developed countries, such regulation is an important constraint on the activities not only of biotechnology enterprises but also of biotech research laboratories, whether in universities or government laboratories. The issue of regulation is probably more important in the area of biotechnology than in most other industrial fields because biological organisms, which constitute the basic elements of biotechnology, interact in complex ways with the biologial ecosystems of which they form a part. Accordingly, adequate care must be taken to ensure that biotech-related activities do not produce negative external effects.

Regulatory measures, particularly in the United States, where much of the more advanced developments have taken place, are having substantial impact on the types of products and processes which are developed. In June 1986, for example, the U.S. Food and Drug Administration approved the first therapeutic use of a monoclonal antibody for the treatment of kidney transplants. Another example, which, however, led to difficulties, was the approval by the U.S. Department of Agriculture (USDA) for marketing of a genetically altered virus. In April 1986, USDA had to review its approval process because of widespread public criticism. In a case of frost-damage prevention testing, it was considered that the company concerned had violated Federal guidelines in testing the product in an open-air roof test. In May 1986, the U.S. Environment Protection Agency did not permit field tests of a genetically engineered pesticide until further safety tests had been conducted. The requirements of further safety testing has resulted in delays in marketing biotech products produced from genetically altered micro-organisms when released into the environment. These developments have not, however, affected other biotech-related products. Many of the smaller biotech companies have designed or are developing products, including diagnostic kits, which would allow them to circumvent this process or minimize possible delays.

Intellectual property rights

Intellectual property rights presently constitute a central aspect of biotechnology. Biotech developments up to the early 1970s were largely in the public domain. In recent years, however, there has been greatly increased privatization of biotechnology through trade secrets, plant breeder rights and through patents (a) on new crop varieties and seeds, (b) on biotech drugs and products and (c) even on new life forms created through gene manipulation, following the U.S. Supreme Court decision in the case of Diamond vs. Chakravarty in 1980. Trade secrets in this field are becoming increasingly popular, since patents in biotechnology are often contested. Patents on live organisms present problems, particularly in the United States, since it is often difficult to define the stage at which an organism or process becomes different enough to be patentable. Plant breeder rights are also protected similarly to patents in the United Sates and in several European countries and can be extended to newly created plants and biological organisms. 4/

There is growing protection of industrial property rights in biotechnology. It is still not clear to what extent some of the original, broader patents will be upheld in court, or to what extent patents on processes or similar products developed by more than one company will be upheld, since several companies are often simultaneously developing similar products. Patent litigation cases, and costs of filing patents themselves, are providing a significant burden for smaller biotech companies. Patent filings are, however, one of the means by which universities and other research institutes can continue to disclose results of research. At the same time, publication of research findings is inhibited until patent applications have been filed.

Patents filed in the United States, for example, are mostly by corporations, and with one or two exceptions of centrally planned economies, all are from countries in North America, Europe, as well as Japan and Israel. Of the 374 patents granted from 1963, to 1984 in genetic engineering in the United States, 222 were to United States corporations, government or individuals. Of these, 188 (85 per cent) were to corporations. Of patents granted to non-United States entities during this period, 123 (87 per cent of foreign-owned United States patents) were to foreign corporations. Of the 152 of foreign origin, Japan, the Federal Republic of Germany, France, and the United Kingdom accounted for 72 per cent. 5/

The increased privatization and commercialization of biotechnology would undoubtedly present serious problems for developing countries. The choice may well be either to provide a greater package of incentives for indigenous research in various biotech fields or to pay the fairly heavy costs of availing of foreign patents in these fields, apart from the growing dependence that this may entail even with respect to agricultural and livestock development, apart from industrial uses of biotechnology.

New products and techniques

The application of biotechnology can result in (a) new ways of producing existing products with the use of new inputs and (b) new ways of producing new products. Examples of the former include the production of gasoline from ethanol which in turn is produced from sugar, the production of insulin using recombinant DNA technology, the production of the hepatitis B vaccine using recombinant DNA technology, and the extraction of copper using mineral leaching bacteria. The alternative inputs are oil for gasoline, porcine pancreases for insulin, human blood for the hepatitis vaccine, and conventional mining techniques for copper. Examples of the latter include possible medicinal substances which are produced in minute quantity in the human body and which cannot be synthesized such as insulin, interleukin, or tissue plasminogen activator (TPA). It is not clear that the biotechnology-based option will always or usually be preferable. For example, although the oil crises of 1973/1974 and 1979/1980 induced a good deal of interest in biotechnology-based methods, the subsequent drop in oil prices led to reversion to oil-based alternatives. In the latter case, it is the demand for the new product that will be the decisive factor in determining the use of the biotech-based inputs. 6/

Extension to new products

In several cases, biotechnology has led companies in industrialized countries to extend their production or marketing to new product groups. Examples are the shift by agrochemical companies in the area of seeds, or the move of fermentation-based companies in areas such as food and alcoholic beverages into new biotech-based products such as pharmaceuticals. The possibility of producing new plant varieties that are herbicide-resistant creates new commercial possibilities for herbicide-seed packages. In order to increase returns from this new potential, large agrochemical companies have been involved in acquiring or setting up seed companies. Similarly, the possibility of developing pest-resistant plants has significant implications for the development of pesticides, enabling the merger of agrochemical and seed research, production and sales activities. 7/

Research and development

Since biotechnology is highly research oriented, a number of companies and institutions, mostly in industrialized countries, have undertaken extensive biotech research. These include research units in government institutions and universities, besides companies whose markets are likely to be affected by new biotechnology or those whose existing technologies are closely related to new biotechnology. Governments in industrialized and developing countries are becoming increasingly involved in biotech developments and several Governments have defined biotech R&D as being of national priority. These include Brazil, Canada, France, India, Japan, Mexico and the United States. Some countries, such as India and Mexico, have drawn up national plans for biotechnology and some others, such as France, Mexico and the United States, have established national biotechnology companies to increase links between R&D and production. In the United States, an estimated $51 million per year is provided for basic research in this field, while Japan is providing approximately $60 million a year, while funding by the Federal Republic of Germany, France and the United Kingdom range from $60 million to $100 million annually. 8/ The extent of involvement of universities and other research institutions in biotechnology differs from country to country. In the U.K. and the U.S.A., for example, universities have played a very important role. 9/ In some other countries, such as Japan and the Federal Republic of Germany, large corporations are undertaking this role to a greater extent. Several universities, particularly in the United States, are now engaged in a race for patents on biotech processes and products. Among companies, TNCs are becoming increasingly involved in biotech research and in the marketing of products and processes based on biotechnology. At the same time, there has been rapid growth of small biotech companies, often financed by venture capital, mainly in the U.S.A. and other industrialized countries. In the United States alone, there are some 200-300 such companies. Table VI.1 provides a list of several agreements beween universities and TNCs, smaller biotechnology companies, and/or governments, both within and between industrialized countries. In the United States, several universities and local governments have set up industrial parks adjacent to universities, as in the case of the University of Missouri, Yale, the Polytechnic Institute of New York, Princeton and Stanford. In France also, corporations are choosing to locate new biotechnology facilities near university centres. Active industry-university linkages in biotech research have developed in several countries. In the United States, where such links are perhaps most numerous, nearly half of the companies engaged in such R&D have arrangemnts with universities. In certain cases, agreements have been entered between companies and universities in different countries, such as the agreement between Hoechst (Federal Republic of Germany) and Harvard University.

The trends in biotech research in industrialized countries have resulted in various areas of growing concern. These include increased secrecy and commercial interests on the part of university faculties, a deflection of research towards more profitable lines of biotech inquiry, lawsuits for damages from products developed from university research, and a change in emphasis from universities competing for the best faculty to competing for the most lucrative fields of research. 10/

The growing role of TNCs

The role of TNCs in biotech research and marketing is expanding rapidly and is reflected in several linkages between major corporations in chemicals, pharmaceuticals and other fields with small biotech companies. The smaller companies often concentrate on R&D and then license production and/or marketing to TNCs with established production facilities and marketing outlets. Alternatively, smaller companies may also attempt production and marketing, at least in their home countries and arrange with TNCs for marketing abroad. A third and more unusual approach is for a major corporation to license a biotech company to do marketing and take care of regulatory problems. In such a case, the smaller company concentrates on one product or product line and develops a marketing system specific to that line of products.

Table VI.2 provides a list of several agreements in production and marketing of biotech-related products and processes. The entrance of major TNCs undoubtedly threatens the ability of smaller biotech companies to compete or survive on their own. Several of these companies have combined with larger firms. For example, Enzo Biochem agreed to give a subsidiary of Johnson & Johnson (Ortho Diagnostic Systems) exclusive worldwide marketing rights (except for Israel and Japan) for DNA probes developed by Enzo. In return, Johnson & Johnson and Ortho invested $20 million in Enzo. In September 1985, Hybritech was acquired by Eli Lilly & Co. for $300 million. In the case of Celltech, a biotech company from the United Kingdom, a joint venture was formed with Boots, called Boots-Celltech Diagnostics Ltd., with a subsidiary in the United States. There have also been several agreements between companies regarding production and/or marketing. Many of these were agreements made in order to obtain financing for R&D projects, or to enable TNCs to control distribution of products. Certain major TNCs have also built extensive marketing networks for biotech products. For example, in 1983, Monsanto acquired Continental Pharma, S.A. (Belgium) to develop a marketing and distribution network in Europe and in 1985 Monsanto acquired G.D. Searle, a pharmaceutical company best known for its sweetener, Aspertame, and with a large sales force. In the agricultural sector, several companies are working on producing herbicide-tolerant crops. TNCs have also been very active in seed production and have acquired seed companies in several countries to control outlets for improved seeds.

Technology flows

Since most of the global effort in biotechnology is concentrated in the industrialized countries, developing countries have a vital interest in international flows of such technology. These will be largely through linkages with TNCs and specialized biotech companies in industrialized countries and will take the form of foreign affiliates, joint ventures, technology licensing, and research contracts. 11/ Less formal linkages can also be formed through several networks and associations. In Japan, about 100 companies formed a trade group to avoid duplication in R&D and hold symposia and train personnel. The charter members of the group include some of Japan's largest TNCs such as Ajinomoto, Toray Industries, Kyowa Hakko Koigyo, Suntory, Sumitomo Chemical, Mitsubishi Chemicals and Hitachi. An important advantage of biotech companies is their access to international capital markets. Biogen, with laboratories in Switzerland and U.S.A., is an example of a publicly-held company with an international equity base with initial funding through investments by Inco, a Canadian mining company, Schering-Plough, a United States-based pharmaceutical TNC, Monsanto, a U.S.-based chemical TNC, and Grand Metropolitan, a hotel and food processing group based in the United Kingdom. Monsanto holds equity positions in several biotech companies in the United States and in Europe, and has been active in funding venture capital firms. There are extensive links between Japanese companies with United States and West European biotech companies. These links include stock purchases, licensing agreements and joint technology development agreements (as between Genentech and Sumitomo Chemical Co.). 12/

Some agreements have also been entered into between biotech companies and developing countries, particularly for testing of drugs. One example is the agreement between the Shaanxi Pharmacetuical Bureau in the People's Republic of China and Biogen for clinical trials of Biogen's gamma interferon. In Malaysia, a joint venture was formed between the International Plant Research Institute, a privately held commercial company based in California, and Sime Darby for the introduction of plant genetic engineering products into Indonesia, Malaysia, and some other South-East Asian countries. While it is difficult to assess the extent of technology flows, there is little doubt that most such flow of biotechnology has so far been between industrialized countries. The links with developed countries are very limited and not much technology has been transferred through these links. Though several TNCs have extensive manufacturing and marketing operations in developing countries, there are relatively few TNC operations so far involving new biotechnology in developing countries. However, this is likely to change, particularly in the pharmaceutical industry, as TNC subsidiaries and affiliates begin to develop and market products based on biotechnology. Another major sector of growing TNC involvement in developing countries is agriculture and, more specifically, seed production and distribution. Several seed companies have been acquired in recent years by TNCs, including in developing countries. Significant segments of the vegetable seed market in many of these countries are already substantially held by TNCs. Suttons (owned by Cardo), Ohlsen Enke (owned by Svalof), and Zaadunie of Holland (owned by Sandoz) are among major suppliers of vegetable seeds to Africa and West Asia. Japanese breeders such as Takii and others linked to Sumitomo and Mitsubishi occupy a leading position in the vegetable seed market in South East Asia. In Latin America and the Philippines, vegetable seed is marketed by several U.S. companies. TNCs are also getting more actively involved in seeds for cereals and foodgrains. They are also able to link the use of fertilizers and pesticides to new varieties of seeds and build a market for other agricultural inputs which they manufacture and market. 13/

There has also been considerable growth of design and construction engineering firms in biotechnology in industrialized countries. Some of these firms have had experience with fermentation technology, including design and construction of breweries, corn sweeteners, antibiotics, enzyme production and yeast production facilities. By the mid-1980s, there was considerable activity among engineering firms for design and construction of laboratories, pilot plants and manufacturing facilities for biotech-related products and processes. In 1984 alone, a review of projects announced in journals showed over $960 million worth of projects either completed or begun in the field. Of this total, some $45 million was for pilot plant construction. Production facilities accounted for $467 million and research facilities for the balance of $457 million. 14/

For developing countries, most of the really critical biotech equipment and supplies will have to be obtained from industrialized countries. There is a degree of vulnerability in the event that access to vital equipment and supplies may be restricted. There may be less problems with supplies of biochemicals and other biotech raw materials. Some developing countries are initiating anticipatory strategies. In India, the Centre for Biochemicals coordinates procurement from abroad of a wide range of biochemicals such as restriction enzymes etc. Efforts are also being made to produce at least some of the principal biochemicals within the country. Countries such as India, Brazil or Mexico also have a relatively advanced scientific infrastructure and can achieve a significant measure of self-sufficiency in consumable supplies. There is, however, little actual experience, because industrial production based on advanced techniques in biotechnology is extremely limited, even in industrialized countries.

Prospects for developing countries

The developments regarding university-industry-government relationships in biotechnology are of special concern to developing countries. There are growing restrictions in the free flow of information among scientists and universities and research institutions. This would be further accentuated with a greater number of agreements between universities and corporations. The latter would insist that results of scientific inquiry be kept secret long enough to file for patents, or for a period long enough to allow the company to gain a competitive edge. Another area of concern involves the increased emphasis of research primarily on products and processes of direct benefit to industrialized countries and towards products and processes which provide high profit margins for the companies involved.

Alternative methods of entry or financing biotech developments in developing countries have also to be considered. In the United States and some other industrialized countries, venture capital has played an important role in financing new biotechnology companies. Advent Eurofund, for example, is funding European ventures, including through major financial support from a United States-based TNC. This alternative may not be available in most developing countries. Public stock offerings may constitute a second means of funding local biotech companies. This alternative may also have limited application in developing countries till biotech developments and applications become better known. TNCs provide a third means of entry of biotechnology through various arrangements, including TNC subsidiaries or joint ventures or TNC-financed venture capital funds; and licensing arrangements between TNCs and local companies. The fourth method is direct government support. Of these alternatives, the latter two appear to be the most promising for developing countries.

International dimensions

There is no doubt that biotechnology, as an interrelated set of technologies, will have considerable effect on a large number of industrial sectors. Process technologies such as recombinant DNA techniques, cell fusion, tissue culture, protein engineering, and bioprocessing can be applied to a wide range of products, extending from pharmaceuticals, such as insulin, interferon, and vaccines, to industrial chemicals, such as enzymes and other proteins, ethanol etc., besides new plant varieties and various applications for agriculture and livestock development. Most of these technologies are still in incipient stages and their implications for future international division of labour and comparative advantage are difficult to define, though biotechnology is already having some impact on production and trade in certain specific areas. Since biotechnology is, however, at an early stage of development, it provides greater opportunity for developing countries to achieve competitive capability, at least in certain fields. This would require, however, an initial base of scientific talent and knowledge, supported by complementary capabilities in developing production facilities, either directly by local institutions and enterprises or through linkages with foreign sources of biotechnology, including TNCs. It may also be necessary to restructure industrial strategy and growth to take full account of agricultural enterprises that produce the inputs for industrial processing, and of biotech-related enterprises and research institutes that may impact on agro-industrial activities.

Co-operation among developing countries

Both the agricultrual and industrial applications of biotechnology provide a challenge and opportunity for many developing countries across a wide range of sectors. While the responses need to be country-specific there are several issues which lend themselves to joint action. These include: (a) co-operation in the development of products particularly suited to developing country conditions, such as vaccines and diagnostics for ailments particularly prevalent in developing countries, (b) co-operation in training for biotechnology, including through exchange of personnel and trainees and through specialization in specific fields, and (c) co-operation in the acquisition of complementary capabilities and complementary assets, including adaptation and incremental innovations with respect to foreign biotechnology.

International co-operation in biotechnology

The need to regulate biotechnology is particularly important in view of the potential ecological risks, and close co-operation with international efforts to establish and enforce codes of practice is essential. It may also be necessary to develop international co-operation, including, perhaps, revised international arrangements with respect to intellectual property rights in biotechnology, particularly on patenting of new organisms and new plant varieties. Patents and breeding rights in biotechnology are likely to have considerable impact on developing countries, and their interests in this regard may need to be adequately articulated through developing country co-operation.

The United Nations system should also ensure greater international co-operation in biotechnology. In a system so large and diverse, efforts related to biotechnology are widely scattered and are mostly modest in scope. Among the agencies concerned with the development of biotechnology to the needs of developing countries are the Food and Agriculture Organization (FAO), World Health Organization (WHO), UNESCO (particularly through its network of MIRCENs or Microbiology Centres for Training and Research), and the United Nations Industrial Development Organization (UNIDO). The most significant of the various initiatives within the United Nations system is the International Centre for Genetic Engineering and Biotechnology (ICGEB), which has grown out of UNIDO's Programme on Advanced Technologies. The ICGEB programme has now been initiated, with two major components being set up, one in Italy and the other in India. The basic objectives of the ICGEB are to enhance biotechnology capabilities among developing countries and to focus this technology on the solution of problems specific to these countries. The Centre's activities will encompass basic and applied research, training of scientists from developing countries and development and delivery of technology to developing countries suitable for application in those countries. While such efforts at international collaboration are very important in ensuring that the positive potential of biotechnology for developing countries is realized, the major endeavour will of necessity have to be made by the developing countries themselves. The stronger the national programmes in biotechnology, the greater will be the ability of these countries to take advantage of international efforts such as the ICGEB.

Notes and references

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2/ Fransman, ibid.

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4/ UNIDO Technology Trends Series No. 6, "Trends in Biotechnology Development and Transfer", by David Dembo and Ward Morehouse, UNIDO document IPCT. 32, June 1987.

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9/ "Corporate-academic ties in biotechnology", Genewatch, September-December 1984. Also, David Noble, "The selling of the university", The Nation, February 1982.

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11/ ibid.

12/ ibid.

13/ ibid.

14/ ibid.

Table VI.1

University/industry/government biotechnology agreements

Country (ies)	University (ies)	TNC/biotechnology company/government	Type	Amount (US$)
United States	Stanford University	Engenics/Center for Biotechnology Research (CBR) (Elf Technologies, General Foods, Koppers, Bendix, Mead, McLaren Power and Paper)	The six sponsors set up Eugenics and CBR, the former as a for-profit company, the latter to fund university research	2.5 million for CBR for four years, 7.5 million for 30% equity in Engenics
United States	Michigan State University (MSU)	Neogen and Doan Resources	Neogen was founded by Michigan State to provide limited partnership funds for faculty and research results	230,000 in stock purchases by MSU, 250,000 by Doan Resources
United States	Rockefeller University	Monsanto	Five-year agreement on photosynthesis research	4 million
United States	Washington University	Monsanto	Support for faculty research in hybridomas	1.5 million
United States	Harvard University	Monsanto	Support of basic research on cancer	long-term agreement
United Kingdom/ United States	Oxford University	Monsanto	Five-year research project on oligosaccharides	£ 1.2 million
United Kingdom	Bristol, Birkbeck College, Oxford, Imperial College, Leeds, York	Celltech, Glaxo, ICI, RTZ Chemicals/Sturge, Science and Engineering Research Council (SERC)	The parties have agreed to a four-year research "club" to study protein engineering and produce novel proteins	£ 2 million
Federal Republic of Germany/United States	Massachusetts General Hospital (Harvard University)	Hoechst A.G.	Research in molecular biology	70 million
United States	University of Illinois	Standard Oil of Ohio	Five-year grant establishing a centre in Crop Molecular Genetics and Genetic Engineering	2 million
United States	Massachusetts Institute of Technology	National Science Foundation	Establishing centre for biochemical engineering including research in genetics and molecular biology	20 million
United States/ Israel	Rockefeller University and the Weizman Institute	Rapid-American Corporation	Research on cancer biology, neurosciences, molecular genetics, immunology	5 million
United States	Northern Illinois University	Argonne National Laboratory, State of Illinois	Project on crop plant growth rates, pest-resistant and chemical synthesizing plant strains	1 million for first year

Table 1. (cont'd)

Country (ies)	University (ies)	TNC/biotechnology company/government	Type	Amount (US$)
United States	Washington University	Monsanto	Five-year contract for research projects including fundamental research (30%) and research into human disease	23.5 million
United States	Massachusetts Institute of Technology	Whitehead Institute (head is President of Technicon Corporation)	Institute to be built and funded, including funding of MIT's biology department's faculty, graduate students and research assistance	20 million for structure, 5 million, to operate, 100 million to Institute upon death of Whitehead, 7.5 million to MIT, plus 1 million annually
United Kingdom	University of Leicester	John Brown Engineers, Dalgety-Spillers, Gallahers and Whitbread and the Science and Engineering Research Council	Five-year research programme	£ 1 million from the four companies, £ 183,000 from the Research Council to equip laboratories.
United States	Cornell University	Union Carbide, Corning, Eastman Kodak	Establishment of biotechnology institute	2.5 million each over 6 years by the companies, 4 million by Cornell
United States	Massachusetts Institute of Technology	W.R. Grace	Research on micro-organisns	8.5 million
United States	Columbia University	Bristol-Myers	Investment in work of molecular biologist involved in gene cloning and rDNA technology	2.3 million
France	University of Compiegne	Elf Acquitaine	Enzyme engineering	N.A.
United States	Harvard	Du Pont	Five-year grant to head of new department at medical school	6 million
United States	Yale	Celanese	Three-year R&D in enzymes	1.1 million
United States	Washington University	Mallinckrodt	Three-year hybridoma research programme	3.88 million

Table 1. (cont'd)

Country (ies)	University (ies)	TNC/biotechnology company/government	Type	Amount (US$)
Federal Republic of Germany	University of Heidelberg	BASF, FRG	Ten-year support of research	1 million DM from BASF, 18 million DM three year grant by the government
Federal Republic of Germany	Max Planck Institute, University of Cologne	Bayer	Support	1 million DM per year
Federal Republic of Germany	Max Planck Institute of Immunology, University of Munich	Hoechst	Collaborative project	n/a
Federal Republic of Germany	National Centres of Excellence at Cologne, Heidelberg, Munich and Berlin	BMFT (Federal Ministry of Science and Technology)	Support of biotechnology projects in universities and government institutes	1.05 million DM in 1983, 1.15 million DM in 1984
United Kingdom/ United States	Universities of Oxford and Cambridge, Imperial College, London	Monsanto, Nuffield Foundation	Advent Eurofund to finance biotechnology (among other) projects	£ 10 million initial capital, half from Monsanto
United States	Brigham Young, California Institute of Technology, Colorado State, Emory, Illinois Institute of Technology, Iowa, MIT, Purdue, State State University of NY at Albany, Texas A&M, Tulane, Universities of California, California at Davis, Cincinnati, Connecticut, Georgia, Idaho, Kansas, Kentucky, Maryland, Massachusetts, Minnesota, North Carolina, Utah	U.S. Pentagon	Funding of genetic engineering research for biological warfare	42 million in 1986 for 57 projects (including six private res-research institutes and four corporations - see below)
United States	Agouron Institute	U.S. Pentagon	Research into applications of genetic engineering to biological warfare	-
United States	N.Y. State Department of Health	U.S. Pentagon	Research into applications of genetic engineering to biological warfare	-

Table 1. (cont'd)

Country (ies)	University (ies)	TNC/biotechnology company/government	Type	Amount (US$)
United States	Salk Institute	U.S. Pentagon	Research into applications of genetic engineering to biological warfare	-
United States	Scripps Clinic	U.S. Pentagon	Research into applications of genetic engineering to biological warfare	-
United States/ United Kingdom	National Environment Research Council	U.S. Pentagon	Reserach into applications of genetic engineering to biological warfare	-
United States/ Israel	Weizman Institute	U.S. Pentagon	Research into applications of genetic engineering to biological warfare	-

Source: Dembo and Morehouse, op.cit.

Table VI.2

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

Table 2 (cont'd)

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	Néstle 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.

Table 2 (cont'd)

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 Endo-tronic.
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..	

Source: Dembo and Morehouse, *op. cit.*

CHAPTER VII

NATIONAL PROGRAMMES IN BIOTECHNOLOGY IN SELECTED DEVELOPING COUNTRIES

While developments and research in biotechnology have been largely concentrated in industrialized, developed economies, efforts and programmes on biotechnology development have also been undertaken in several developing countries. The programmes and initiatives undertaken in eight developing countries, namely, Brazil, India, China, Mexico, Thailand, Argentina, Cuba and Nigeria are described in this chapter.

Brazil

The main strategy adopted by Brazil in relation to biotechnology development is one of import substitution to achieve a position of relative autonomy. In Brazil, biotechnology programmes are co-ordinated under PRONAB (Programa Nacional Biotechnologia do Brasil), which was established under the National Council for the Development of Science and Technology in 1981. The purpose of PRONAB is to establish the necessary infrastructure for biotechnology research and development. In 1985, a special secretariat for biotechnology was set up under the Ministry of Science and Technology. In 1986, a three-year programme for US$ 100 million for development of biotechnology was established, which covers 20 important products for Brazil's national self-sufficiency. Brazil also obtained $546 million in World Bank funding for development, approximately 55 per cent of which would be spent on research in biotechnology, chemistry, and industrial technology. 2/ The market for biotechnology is expected to reach $440 million by 1990. The immediate goal is to co-ordinate biotechnology research, and to provide scientific and commercial support. 3/

Foreign biotechnology firms in Brazil include Bristol Laboratories, Pfizer, Novo Industri do Brasil, and National Distillers. A Brazilian-Argentine biotechnology centre which opened in the spring of 1987 is to study waste treatment and the use of sugarcane waste. Two domestic biotechnology companies concentrating in the agricultural sector are Biomatrix and Bioplanta, which are to sell virus-free strawberries and potatoes to Brazilian farmers. 4/

Biotechnology is most advanced in agriculture, where the principal focus is on improving production through the use of tissue culture and genetic engineering, developing nitrogen fixation micro-organisms adopted to different conditions, increasing photosynthetic efficiency, improving biological pest control, and increasing animal husbandry productivity. Plant tissue culture research is being carried out at several centres including CENA, Planalsucar's Research Centres and IAC (Caminas Agronomy Institute). Agricultural and food products and processes which are being developed from biotechnology include pesticides and fungicides, nitrogen fixation, tissue cultures of vegetation, milk products, beverages, fermentation (yeast) additives, glucose and fructose. The five principal products with potential commercial value are beer and distillation processes, cheese and other lactose products, fermentation of bread, organic acids (mainly citric), and antibiotics. 5/

In the energy sector, the main emphasis is on the Brazilian National Alcohol Program. Techniques used for this programme involve plant cell and tissue culture, including plant cloning techniques for sugar cane with greater tolerance to herbicides. Research is also being conducted on nitrogen fixation for sugar cane which may reduce fertilizer costs if successful. 6/ Research is also being conducted for finding new or improved micro-organisms for converting starchy and cellulosic materials to sugars for ethanol production. 7/ Brazil's ethanol project is designed to provide a viable energy alternative. 8/

A new biotechnology centre in Rio de Janeiro was set up in 1987 called Bio-Rio with the purpose of strengthening university-industrial ties with an initial investment of US$ 24 million. The Brazilian Biotechnology Association has 30 members, and it is estimated that there are more than 60 biotechnology companies. These are usually initiated in response to short-term needs, rather than a long-term integrated plan. There are approximately 30 research centres, both public and private, in Brazil, of which 16 are working on plant biotechnology. Fifteen have tissue culture laboratories. Modern genetic engineering techniques, such as recombinant DNA to crop plants are applied at the National Research Center for Genetic Resources (CENARGEN) in Brasilia. CENARGEN was established by EMBRAPA, the Brazilian Agricultural Research Enterprise, in 1974 to co-ordinate research in plant and animal germ plasm. The Brazilian campaign for self-sufficiency in immuno-biologicals requires substantial increase in the production of sera and vaccines which are important for dealing with infections and parasitic diseases. Priority has been given to the production of anti-venoms, especially against snakes.

In the private sector, Souza Cruz is one of Brazil's largest private companies concentrating on biotechnology, with an investment of $12 million. Bioplanta is a subsidiary of Souza Cruz, founded in 1983.

Brazil stands out among developing countries in terms of biotechnology capability, and is one of the few countries with a formal national biotechnology programme. However, the country is dependent on foreign technology and joint ventures for more advanced technological processes and the industry relies on processes and products already in existence. The country is most advanced in agriculture and fermentation technology in the field of biotechnology, but is more dependent on foreign technology in health and pharmaceuticals. 8/ Both in Argentina and Brazil, several universities conduct programmes relating to vaccines and diagnostic kits in the livestock sector.

In 1965, EMBRAPA began to identify and reproduce native strains of soya beans for the production of inoculants to substitute them for nitrogen fertilizers. There are seven factories which produce significant amounts of these inoculants in Brazil, but there are problems due to contamination or lack of proper fermentation equipment. 9/ Brazil's pesticide production is much more advanced. In March 1988, Brazil had ten culture collections. In pharmaceuticals, national production depends largely on the import of drugs and raw materials.

Obstacles which Brazil faces in development of biotechnology include lack of skilled and specialized human resources, training and infrastructure. In addition, there is lack of finance for research and the major R&D centres are isolated. There is also difficulty in obtaining and maintaining equipment, and weak links between the Government, industry, and universities.

Brazil's ethanol or alcohol fuel industry has recently been facing some difficulties. The cost of the fuel is fairly high, and alcohol is less efficient than petrol. In addition, the large sugar cane fields could also be used to grow food or export commodities like soya beans. In the longer run, however, the alcohol fuel programme would be viable as other energy sources get depleted, and as fuel and production efficiency improves. In the health and pharmaceutical sectors, however, Brazil has relied mainly on joint ventures with major TNCs. 10/

Much of Brazilian research in biotechnology relies on traditional methods, including industrial processes that manipulate whole microorganisms and plants, enzymology, classic genetic improvements, plant selection and fermentation. Some of the research institutes are, however, moving into modern biotechnology, based on recent advances in genetics, molecular biology and cell-tissue culture. On the whole, Brazil's biotechnology programme has proceeded fairly satisfactorily.

India

The principal agency for formulating and implementing government policies in biotechnology in India is the Department of Biotechnology in the Ministry of Science and Technology of the Central Government. The Department's major programmes include: (a) integrated plans in biotechnology, (b) identification of specific R&D programmes in biotechnology and biotech-related manufacture, (c) infrastructure support; (d) to act as agent of the Government for import of new recombinant DNA-based biotech processes, products and technology, (e) to evolve bio-safety guidelines, (f) to develop specialized biotechnology skills and (g) to set up the International Centre for Genetic Engineering and Biotechnology. 11/

The objectives in biotechnology are to develop indigenous technology and ensure efficient absorption and adaptation of imported technology appropriate to national priorities and resources. The long-term biotechnology plan has listed several broad goals. The main policy elements are, however, reflected in the major areas of activity of the Department of Biotechnology. These include manpower development, infrastructural facilities, R&D programmes, international R&D collaboration and major science and technology "mission" projects, such as embryo transfer technology and development and production of immunodiagnostics.

An important policy aspect in India relates to incentives for industrial research. The Government provides a variety of such incentives for research and development generally, including but not limited to biotechnology. There are also several incentives for commercialization of indigenous technology. These include preferential treatment in industrial licensing and other special arrangements for companies using indigenous technology. The National Research Development Corporation (NRDC), a State-owned company, also implements a number of schemes, such as financing the scale-up of research through pilot plant and demonstration units, equity investment in companies based on know-how licensed through NRDC, and export of indigenous technologies.

Industrial property rights in India are defined in the Indian Patents Act of 1970, which came into force in 1972. This legislation abolished patents on chemical compounds and drug formulations, reduced the term for process patents for drugs, food, and medicines to five to seven years (compared to a term of 14 years for other patents), and made patents liable to be revoked for non-use under certain circumstances. Other features of the Act include a provision for licensing of all chemicals, food, drug, and medicine patents and a maximum royalty of four per cent. New varieties of plants were specifically held to be non-patentable. In recent years, there has been some discussion of the possibility of changing some of these provisions, including recognition of plant breeders' rights. 12/ Indian patent laws protect only technological processes for producing food, medicines and chemicals, not the products themselves.

The Department of Biotechnology has supported post-graduate and post-doctoral programmes in biotechnology in 13 institutions in the country. These institutions include some of India's leading universities and research institutes, including the Institutes of Technology, the Indian Agricultural Research Institute and the All India Institute of Medical Sciences. The Indian Institute of Science in Bangalore has instituted a post-doctoral research training programme in biotechnology and life sciences with the number of students admitted each year ranging from three to 20. Other manpower development programmes include short-term training courses in biotechnology, the Biotechnology Associateship Scheme, the Visiting Scientist Programme, and a training scheme for technicians. The Biotechnology Associateship Scheme provides support to Indian nationals conducting advanced research or undergoing specialized training in both India and overseas. By 1987-1988, 35 associateships had been awarded (31 overseas and 4 within India) and another batch of 17 scientists selected for awards in the following year. The Visiting Scientist Programme supports Indian scientists from abroad who undertake research in institutions in India for periods of three to six months.

Emphasis has been given to the development of infrastructure facilities for teaching, research and industrial activities in biotechnology. A useful facility is provided by the Biotechnology Information System, which includes an Apex Centre at the Department of Biotechnology and nine information centres in the following fields at various institutions in the country: genetic engineering; animal cell culture and virology; plant tissue culture, photosynthesis and plant molecular biology; oncogenes, reproduction physiology, cell transformation, nucleic acid and protein sequences; immunology; enzyme engineering, immobilized biocatalysts, microbial fermentation and bioprocess engineering.

R&D programmes supported by the Department cover a wide range of subjects including three major projects, namely, propagation of bamboo by tissue culture, formulation of larvicides against malaria, and bio-leaching of low-grade copper ore. New projects approved in 1987-1988 include a Centre for Research and Training in liposome technology, gene cloning of synthetic human insulin, and development of improved strains of methane-producing bacteria. 13/ The Department of Biotechnology has also established a programme for indigenous production of biochemicals such as restriction enzymes and reagents for DNA synthesis at the Centre for Biochemicals on the Delhi University campus. This centre also operates a centralized facility for the import and supply of biochemicals for research institutions throughout the country.

Two programmes of the Department involve 5NT (Mission Mode) projects and technology missions. Among projects under those two programmes are embryo transfer technology (for cows and buffaloes), production of immunodiagnostics, immunological approaches to fertility control, technology mission on vaccination and immunization for low-income sections of the population, and technology mission on oilseeds.

Financial allocations from the Government for support of biotechnology have increased steadily during the 1980s. For the Seventh Five-Year Plan (1985-1990), $400 million has been allocated. Most of the work in biotechnology in India today is conducted in the public sector and undertaken through government bodies. However, there is growing interest outside of the Government in both the non-profit and industrial sectors. Thus, the Centre for Advancement of Biotechnology was established as a non-profit voluntary scientific research organization in Bangalore in 1987. The Swedish pharmaceutical company, A.B. Astra, has joined with the Indian Institute of Science, Bangalore, to establish a Centre for Basic Research in genetic engineering and biotechnology. There is also some research being conducted on biotechnology at the R&D facility of Hindustan Lever, Ltd., a subsidiary of Unilever, and by various public-sector companies producing drugs and related products. Other TNCs which are establishing R&D facilities in biotechnology in India include Pharmacia and Hoechst.

There are several global trends in biotechnology which are significant for the development of biotechnology in India. One of the most important is the increasing privatisation of technological knowledge. This trend is reflected in the activities of several TNCs that have either set up or are exploring the establishment of R&D units in the country. It is also reflected in the promotional activities of the Department of Biotechnology in seeking to obtain foreign technology inflow in biotechnology through Indian companies. Foreign companies are attracted to India, among other reasons because of considerably lower research costs and the substantial pool of trained scientific and technical personnel.

A more problematic trend is the attraction of highly qualified Indian personnel to foreign R&D centres, which typically provide substantially higher compensation and better research facilities. India's response to such a brain drain is found in schemes such as the Visiting Scientist Programme, Overseas Associateship Scheme, and the North American Advisory Committee, which are designed to increase links with advanced centres of research in industrialized countries and to attract Indian scientists back to India, for short periods or permanently.

Research priorities for biotechnology in India are of considerable importance. Emphasis on biotech research at the global level, at least where it involves more advanced techniques of genetic engineering, has been on human health, with secondary attention to agriculture and animal husbandry, food processing, and energy. It is to be considered if this sector deserves equal emphasis in India also. An important exception would be research on vaccines for endemic diseases, which could bring immediate and direct social benefit to poorer sections in the country.

India has several advantages which augur well for its programmes and policies in biotechnology which are still in an early stage. These advantages include relatively abundant trained manpower, substantial infrastructure for advanced scientific research and technological development, substantially lower research costs than in industrialized countries, and Government's recognition of the potential importance of biotechnology. Notwithstanding these advantages, however, and the relatively short time period in which to show significant results, India's programmes in biotechnology may face major constraints. Apart from the continuing drain of scientific talent to foreign institutions, there are relatively weak links between R&D and the productive sectors of the Indian economy. Yet another area of concern may relate to research priorities. The Indian biotechnology programmes may need to concentrate more on agriculture, which provides major biotech potential for the country. Research in agriculture is also more important because of lack of research in the West on tropical plants. There may be need for closer co-ordination between the Council for Agricultural Research and the Department of Biotechnology. 14/

It is too early to assess the success or otherwise of India's biotech development programme. The country's size and population, its large pool of scientific personnel and the country's substantial efforts to build up its national capacity in science and technology indicate major potential for biotech development in the next decade.

China

The People's Republic of China has a long history in the use of traditional biotechnology, but has been involved in modern biotechnology since around 1975 after successfully cloning and expressing foreign DNA in *E. coli*. In 1980, a development programme for biotechnology was outlined by the State Commission of Science and Technology (SCST). 15/ China's main policy goals in biotechnology have been to improve and innovate equipment and technology, to reduce imports of biotechnology products, and to strengthen basic research. 16/ An important aspect has been to improve co-ordination of research. Links between universities and industry, and between research institutes themselves, have been inadequate and the Government has sought, through increased funding and contacts, to achieve closer linkages between universities and industries. It has also enacted laws and regulations on joint ventures and on patents in order to encourage foreign investments. A more open policy has been adopted, particularly by encouraging the coastal areas to become more export-oriented. 17/

Long-term national priorities for specific biotech fields are new varieties of high-yield, disease-resistant plants and animals; new medicines and vaccines; food processing and protein and chemical engineering. Short-term national policy goals are geared to reaching the market by the early 1990s. More than half of the budget for science and technology development in the Seventh Five-Year Plan has been allocated for gene and cell engineering and development of new products and processes for agriculture, pharmaceuticals, environmental protection etc. Forty-five per cent of the budget for biotech R&D will be for development of fermentation and enzyme engineering, and transferring the results to the productive sector. 18/

In order to promote inter-disciplinary and inter-institutional co-operation, "open laboratories" have been set up in which most of the research staff is made up of visiting fellows from different universities, production sectors, and even foreign countries. Some of the open laboratories include the Laboratory for Molecular Biology, the Research Institute of Microbiology (virus, enzymology, genetics, microorganisms), the Experimental Marine Biology Laboratory, and the Beijing Laboratory for Structural Chemistry of Unstable and Stable Species.

The principal co-ordinating agency for biotechnology in China is the National Centre for Biotechnology Development in Beijing, which was set up in 1983 under the State Science and Technology Commission, and is responsible for financing major projects, and providing the necessary equipment. The Centre promotes university-industrial links and the transfer of R&D from laboratory to industry and for commercialization. The Centre also provides financial and technical assistance for biotech research, including pilot plants, and is investing US$ 25 million to set up a modern biotechnology experiment base in Beijing and Guangdong. The research base in Beijing will focus on genetic engineering (gene isolation, recombination etc.), cell engineering (monoclonal antibodies, cell fusion for new animal and plant varieties, etc.), enzyme engineering, fermentation technology (amino acids, antibodies etc.), and reactor engineering research.

Six institutions are affiliated with the National Centre, including the Institute of Microbiology, the Laboratory of Molecular Biology for Agricultural Sciences, the Scientific Research Institute of Food and Fermentation Industry, the Institute of Virology, Tsinghua University, and the Institute of Biophysics. Until recently, nearly all biotech R&D was done in government institutions. 19/ However, a few years ago the Government initiated new policies for setting up private research and development units, especially for serving rural enterprises. Since 1987, the number of private research units and companies has doubled, now numbering over 11,000. Many are spin-offs from State-owned institutions. In order to encourage entrepreneurship, tax incentives have been provided to those firms and funding is also available. Incentives have also been provided to professors and researchers to serve as consultants to enterprises.

The restructuring of China's R&D system is still in its early stages. Many large State-owned enterprises with inadequate R&D capability are merging together to combine their strengths and minimize their weaknesses. Others have sought foreign partnerships to modernize.

With respect to information and library services, China publishes a journal entitled the Chinese Journal of Biotechnology which reports on Chinese achievements in the field, and is available in English through the Chinese Academy of Sciences in Beijing. A gene library for rice was begun in 1982.

The new patent law enacted in 1985 includes microorganisms, and provides for a deposit of the organism at a Chinese depository for those seeking a Chinese patent. Product patents are not recognized, but patents may be granted for manufacturing and production processes. Foods, drinks, drugs, plant and animal varieties etc. cannot be patented.

Two specific programmes on biotechnology deserve special mention. One is the "Spark Programme" for technical and financial support to the rural economy, and focusing on tissue culture technology, microbial pesticides, domestic animal embryo transplantation, and hormones to speed animal growth. The second programme, known as the "Torch Programme" offers technical and financial support to industrial enterprises to promote commercialization of R&D results. The National Research Centre is responsible for technology assessment, formulating biotech policy and evaluating the results. An estimated 4,000-5,000 science and technology personnel are engaged in biotech-related research in China. 20/

In agriculture, tissue culture techniques have been used for many years. More than 20 haploid crop plants have been created, of which wheat, corn, rubber and citrus are ranked first in the world. Many new rice varieties are in large-scale field tests. A simple biotechnique for introducing exogenous DNA into plants after self-pollination has been applied to cotton and rice in China for several years. Disease resistant genes have also been successfully transformed. Basically, biotechnology in agriculture blends some new biotechnology techniques with traditional plant breeding. The "Spark Programme" has focused on dissemination of tissue culture technology, developing new breeds of fresh-water fish, microbial pesticides, animal embryo transplantation, diagnostic agents for animals, and hormones for animal growth.

In the health care field, antibiotics have been produced in China for the last 30 years. The country is also one of the largest producers of Vitamin C, much of it for export. Research has also been focused on interferon and B-hepatitis vaccine for several years. Both have since entered the pilot plant stage. In addition, some monoclonal antibody diagnostic agents have also been developed. On the industrial side, there are approximately 40 factories which produce at least 60 enzyme preparations. Immobilized enzymes are now used in the production of penicillin, and high-fructose syrup is now on the market. Enzyme engineering is one of the top priorities in China's biotechnology field. Biogas containing methane is produced using industrial or farm waste, and distributed through a pipeline to rural areas. Microbial leaching of ores such as copper and uranium has been used on a small scale.

China's enormous market potential has made it attractive for TNCs involved in biotechnology. Squibb (U.S.) Pharmaceutical Company was one of the first TNCs to enter into a joint venture in China in 1983, and formed Sino-American Shanghai Squibb with their Chinese counterparts. Other major joint ventures include Biogen (Geneva), which signed an agreement with the Chinese pharmaceutical firm, Shaanxi Pharmaceutical Bureau, in 1984. Biotech (U.S.), Promega (U.S.), Genetic Diagnostics Corporation (U.S.), and Nippon Zeon (Japan) are also engaged in joint ventures with China in biotechnology. 21/

In the pharmaceutical sector, antibodies against polio virus, hepatitis B, Epstein-Barr virus, malaria, and others have been obtained. Certain problems persist, however, which hinder commercialization such as establishing standard techniques, and stable, simple diagnostic procedures to enable mass production of monoclonal antibodies. China's antibiotic industry is highly integrated with production of more than 80 antibodies. However, penicillin and cephalosporin, popular in industrialized countries, only account for about two per cent of China's antibiotics.

Plant genetic engineering is still in its early stages in China, though plant tissue culture techniques are well developed. Research on wheat, corn, rubber, poplar and citrus haploid plants is of high standard. Some problems in this field relate to transfer of research results to production. In addition, techniques for cell screening, lack of efficiently designed bioreactors for large-scale plant cell culture, and maintaining stock materials with stable genetic traits also constitute obstacles in transferring results from the laboratory to commercial production.

In comparison to biotech R&D in industrialized countries, China is still fairly behind. There is a shortage of skilled and specialized personnel and the technological level is often outdated, besides lack of modern equipment and processes. Owing to inadequate co-ordination in the past, there has been repetition and duplication of research projects. There have also been difficulties in the transfer of research results to the production sector. Better linkages are needed between universities and industries. Some new biotechnology products have, however, reached the market, although in limited quantity. They include monoclonal antibody diagnostics, high fructose syrup, single-cell proteins, microbial pesticides, new enzyme preparations and some virus-free meristem culture.

China has been involved in new biotechnology since 1975, and there has been considerable progress in the field. There continue to be several constraints, including inadequate basic research in molecular biology, the need to import a number of enzymes and chemicals, reliance on foreign technology, and the need for greater exchange of information with the outside world. Nevertheless, in the last few years, there has been significant development of biotechnology in China, including use of recombinant DNA techniques. For example, there has been cloning of the surface antigens of the hepatitis-B virus, the genetically engineered human alpha-interferon gene has been expressed in E. coli, and the penicillin acylase gene has been cloned and expressed. These successes demonstrate that Chinese scientists have absorbed rDNA techniques, and that there is a highly capable pool of technologists concentrating on biotech developments in China.

Mexico

The most important areas of biotech research in Mexico are in health, food, and agriculture. Mexico's policy goals for biotechnology development include personnel training, better linkages between Government, academia, and industry, and improved measures to attract foreign investments with protection of Mexican national interests. 22/

In the agricultural sector, Mexico is using plant tissue culture techniques to apply to various fruits, potatoes, corn, and sugar cane. Mexico has had experience in the production of agave heneguero for tequila, but commercialization has not yet been achieved. The production of single-cell protein for feed is being examined as Mexico imports large amounts of protein for feed and various options are under consideration, including cultivation of yucca for such production.

There is a large market for pharmaceuticals in Mexico, particularly antibiotics. Mexico imports considerable quantities of penicillin, erythromycin etc. Local production of semisynthetic penicillin is carried out by traditional methods which are at a disadvantage as compared to new enzyme biotech processes. The same is true for the production of vitamins, which account for 38 per cent of the domestic market for pharmaceuticals. Regional vitamin production is low and carried out by traditional methods. The National Autonomous University in Mexico (UNAM) is conducting a project for producing Vitamin B_{12} by fermentation.

Most biotech research in Mexico is in the public sector, and is conducted at the universities, research institutes, or federally-owned technology institutes. Linkages between industry and research have been weak. Government institutions have functioned as partners with several companies and

TNCs in the past, but their participation has diminished in recent years. 23/ There are a few national companies also engaged in biotech-related research.

In the food sector, there are some companies which produce yeast. One of these is FERMEX, which produces amino acids. Others are Albamex, based on Japanese technology, and Sosa Texcoco, which produces algae spirulina. The last two companies are government-owned. In the health sector, seven human vaccines are produced by a government laboratory. There are several companies involved in traditional diagnostic systems. Cibiosa, a joint venture, covers the domestic market for penicillin. TNCs involved in producing antibodies by fermentation processes in Mexico include Pfizer, Fermic, Upjohn, Abbott and Cyanamid. In the chemical and industrial fields, Quimica-Meana produces citric acid. Pfizer and Enmex have fermentation plants where enzymes are produced. Industrial waste-water treatment is being handled by several companies who have built water purification systems. Production of biogas and bioleaching of copper is also taking place in the private sector. The most important vaccines for livestock are produced by both public and private companies. There are seven companies that produce inoculants.

Although biotech initiatives have largely been through the public sector, joint ventures, both public and private, are also used as a means of acquiring technology. For example, FERMEX adapted foreign technology to suit Mexico's need for several amino acids, and the Biochemical Industrial Centre did the same in the production of penicillin. 24/

The National Research Council for Science and Technology (CONACYT) is the main financing and co-ordinating agency for biotechnology in Mexico, though biotechnology is only one of the areas covered by the agency. CONACYT finances a minimum of 200 research projects per year, and some additional 200 are funded by other grant agencies. CONACYT also provides a special scholarship programme for biotechnology, including for foreign studies.

The Mexican patent and trademark law of 1976 was recently amended. According to the law, neither plant nor animal varieties, nor biotechnological processes can be patented. In addition, food, drinks, fertilisers, herbicides, fungicides and general medicines cannot be patented. However, a certificate of invention is available to cover biotechnology processes and products. 25/

Funding for biotech and other research is provided by CONACYT and other State and private agencies. Some grants are also provided by international organizations. Limited funding is generated by the biotechnology development sector itself. Other sources of funding include FOMIN, FONEP, FONEI and FOMEX, all national agencies. There are also various programmes to support science and technology and to promote linkages between universities and the production sector. These include the Shared Risk Programme of CONACYT, the Programme of Financial Support for Technological Development of the Bank of Mexico, and the Venture Capital Programme of the National Industrial Development Fund. The Shared Risk Programme is designed to foster linkages between the industrial and research sectors and programme funds projects from 25 per cent to 75 per cent of research costs. The programme sponsored by the Bank of Mexico is for industrial equipment and helps support all the stages needed to introduce technology development.

There are 20 consolidated research groups and 11 pilot plants for biotechnology. Eight of the major research institutes include the Research Centre for Genetic Engineering and Biotechnology of the National Autonomous University of Mexico (UNAM). The Research Centre consists of about 22 researchers, and concentrates on the health and food sectors. The Research Centre for Nitrogen Fixation of UNAM has about 25 researchers in genetics, molecular biology of plants, and nitrogen fixation, with an investment of about $4.5 million. The Institute of Cellular Physiology at UNAM includes 29 researchers in bioenergetics, metabolic regulation, and neuroscience. The Institute of Biomedical Research at UNAM has a fermentation pilot plant, a department of immunology, and a department of biotechnology. The Centre for Research and Advanced Studies at IPN has 27 researchers and 69 graduate students. Research is concentrated on molecular biology in relation to biomedicine. The Department of Biotechnology and Bioengineering at the Centre for Research and Advancd Studies has 16 research laboratories. Research focuses on food technology, enzyme technology, and environmental problems. The department has 26 researchers and a fermentation pilot plant. The Modern Plant Biology Unit at the IPN Centre for Research and Advanced Studies consists of 27 researchers, largely engaged in genetic engineering of plants to improve selected varieties, and to increase yields and disease resistance.

Mexico is a major producer of four amino acids: DL-methionine, L-Lysine, L-Leucine, and glutamic acid.The first is produced by traditional methods, but the other three are produced by fermentation. One of these companies is Fermentaciones Mexicanos (FERMEX) of which the State owns 60 per cent and two Japanese companies (Kyowa Hakko and Sumitomo) own 40 per cent and which began operating in 1978. Mexico is now a major producer of L-Lysine, and supplies the entire domestic market. The Centre for Technological Innovation of the National University of Mexico (UNAM) has played an important role in patenting monoclonal antibodies for the diagnosis of amoebiasis. Other diagnostic systems include DNA hybridization probes. On the industrial front, Mexico produces enzymes for industrial purposes such as lactase and penicillin-amidase, and is working on the production of biogas and bioleaching systems for copper and improved oil uptake. 26/

Mexico has a mature and fairly efficient traditional biotechnology industry which can serve as a sound foundation for modern biotechnology. A fairly promising infrastructure exists, but there is indequate financial support, besides constraints in availability of equipment and industrial services.

Thailand

The principal agency for policy formulation and co-ordination for biotechnology in Thailand is the National Centre for Genetic Engineering and Biotechnology (NCGEB), created in 1983 by the Ministry of Science, Technology and Energy. 27/ The primary institutions affiliated with the agency are Chulalongkorn University, Mahidol University, Kasetsart University, King Mongkut's Institute of Technology, Chiang Mai University, Khon Kaen University, Prince of Songhla University, Srinakharinwirot University and the Thailand Institue of Scientific and Technology Research. Another major support agency for biotechnology R&D is the Science and Technology Board. 28/ Thailand's policy goals in biotechnology are to promote university and industrial links, to co-ordinate government and international support for biotechnology institutions, to transfer R&D from the laboratory to industry, and to improve small and medium-scale bioindustry. 29/ Thailand's objectives entail the promotion of biotechnology products for export, the promotion of local products competing with imports, the improvement of mechanisms for acquiring foreign technology, and the support of R&D and manpower training. These aims require adequate financing, closer links between the public and private sectors, better-trained manpower supply, and improved laws and regulations governing patents, genetic resource conservation and safety issues.

NCGEB is directly engaged in the funding of research projects, the promotion of transfer of technology and information to industry, and the development and construction of pilot plants. NCGEB also provides research fellowships for post-graduates, sponsors workshops and seminars on genetic engineering and biotechnology and provides technical and information services. It also maintains culture collections and acts as a clearinghouse for some microorganisms for researchers. NCGEB co-operates with institutes in the United States, United Kingdom, Australia, Netherlands, Japan and other ASEAN countries. For example, USAID helped NCGEB to form the national network for plant tissue culture technology. A programme on enzyme technology has been developed with the United Kingdom. With Australia, there is a programme to promote joint commercial ventures with industries in both countries. The Netherlands has provided plant genetic engineers for lectures and workshops at NCGEB-affiliated laboratories. Japan has assisted in establishing R&D training and facilities at the National Agro-Industrial Biotechnology Center. NCGEB gives support to affiliates in setting up laboratories and publishes Biotechnology Business News bi-monthly and compiles information on biotechnology, including collection of reference books and leading journals. On-line information services are available to all projects supported by NCGEB.

The Science and Technology Development Board (STDB) is the agency responsible for administering projects and increasing interaction between the research and business sectors. Its functions are to strengthen science and technology intitutional framework, administer an R&D funding support programme, and review science and technology policy and practices. STDB's funding of $49 million is from grants and loans provided by USAID and the Royal Thai Government. A Technical Information Center (TIAC) is being established for the R&D and business communities as a modern information facility. It will draw upon universities, government research laboratories and private consulting firms.

Most of Thailand's biotech programmes relate to the agricultural sector. At Chiang Mai University, there is a project for improving yeast strains for the production of food yeast. Embryo transfer technology is being used on dairy cattle at Kasetsart University, as well as the production of disease-free potato seeds on a commercial scale and the develoment of micro-organisms for compost production. Biotechnology is also used in the development of flowering and ornamental plants. Steroid immunisation is being used at Chulalongkorn University to enhance fertility in the swamp buffalo; and scientists are also engaged in N_2 fixation bacteria research for rice, and mushroom cultivation. Mahidol University is involved in strain selection and cultivation of terrestrial snails for export and the production of mosquito larvicide and field trials of mosquito control using spore-forming bacteria. The use of low-cost cassava for non-toxic, natural colourings for foods, drinks, and pharmaceuticals is being researched at Kasetsart University. A red fungus was discovered capable of producing red pigments from cassava in liquid culture. 29/ In the health and pharmaceutical sector, Thailand is engaged in the production of glucoamylase and pure glucose at Chulalongkorn University, and citric acid production in submerged cultures at Kasetsart. The molecular cloning of Herpes Simplex Virus Type 2 NDA is being investigated at Mahidol University. In the industrial sector, the treatment and utilization of tapioca starch waste water is being addressed at King Mongkut's Institute of Technology. As will be evident from the above, most biotech research and development is being carried out in universities rather than in the industrial sector. For human resource development, NCGEB provides information and training, university-industry links, and some scholarships to students. There are presently about 500 persons directly engaged in biotechnology, but there is a severe shortage of PhDs in the field. 30/

Various fields of research which are being promoted in an effort to displace imports are also largely agriculturally related. These include pure glucose, disease-free potato seeds on a commercial scale, N_2 fixation for rice to reduce fertilizer dependence and local production of the Shiitake mushroom. Possible areas for the future are in biopesticides, biofertilizers, food colours and flavours, diagnostics, antibiotics, and vaccines. Future technologies employed may include genetic engineering, nucleic acid probes, monoclonal antibodies and enzyme production.

The infrastructure for biotechnology in Thailand is relatively strong. Research in biomedical and agricultural sciences is fairly effective, though bioprocess engineering is still weak. In a survey of 40 firms covering eight biotechnology sectors in Thailand, aquaculture was rated the highest in Thailand, followed by food, seeds and dairy industries. Plant tissue culture, fermentation, and health-related biotechnology firms were rated with lower capabilities.

A sound beginning in biotech research has been made in Thailand. Efforts are being made to improve the infrastructure and human resources and several collaborative biotechnology programmes exist between Thailand and other countries.

Argentina

The Science and Technologyy Secretariat, SUBCYT, is the co-ordinating and monitoring body for biotechnology in Argentina and for the National Programme of Genetic Engineering and Biotechnology. This programme specifies priority areas for research. The national institutions for the promotion of science are CONICET (National Council for Scientific and Technical Research), INTI (National Institute of Industrial Technology), and INTA (National Agricultural Research Centre). Combined with governmental agencies, these institutes promote and engage in R&D in biotechnology. 31/

The major policy goals in biotechnology are the achievement of domestic self-sufficiency in areas of heavy reliance on imports such as potato seeds, the development of markets for locally-developed products, the use of agricultural wastes, the ability to develop enzyme technology and the use of biotechnology as a basis for future industrial growth, particularly in pharmaceuticals. More specific goals of the Argentine biotech effort are genetic improvement of plants, nitrogen fixation, drought resistance and vaccines. The main emphasis is on the agricultural and health sectors. Emphasis has been given to four basic areas of research, namely, production of measles vaccine, production of DPT vaccine and hepatitis B vaccine, and production of viruses for developing diagnostic methods for hepatitis B and HIV. Training is being arranged through the Regional Programme of Latin America in large-scale production of cell cultures, bacteria and viruses.

Funding for science and technology is mainly from budgetary allocations and research and development appropriations account for approxiamtely 0.7 per cent of the GDP. The National Biotechnology Programme has a $1 million budget which is administered by the Department of Science and Technology, in addition to $2 million contributed under the Argentine-Brazilian Biotechnology Agreement. 32/

Argentina provides interdisciplinary training and research in its universities, and the Buenos Aires University has a curriculum in biotechnology. A number of courses are also organized annually by research institutes and several co-operation treaties and training programmes are in operation. Fellowships are provided for foreign graduate students, especially from other Latin American countries.

Patent protection is granted for DNA expression vectors, modified plasmid, or procedures for producing microorganisms. Argentina is the only Latin American country which provides for the deposit of microorganisms. With the exception of Chile, Argentina is the only Latin American country which provides specific protection for plant species. There are restrictions for the introduction and transportation of exotic or pathogenic microorganisms. No guidelines have been established so far for recombinant DNA, but there is a concensus in the scientific community to follow the guidelines of the U.S. National Institutes of Health. 33/

The most developed area of genetic engineering and biotechnology in Argentina is the livestock and agricultural sector. Argentinian scientists have programmes for developing vaccines for foot and mouth diseases prepared by genetic engineering techniques, diagnostic kits for animal virus disease and production of animal pathogenic microorganisms for use in vaccines for improved animal health. In the private sector, Argentina is engaged in the production of selected cattle embyros through a joint venture with Biotica S.A. of Argentina and International Cattle Embryo, Inc., of the United States. A number of companies have experience in artificial insemination. The private sector is also active in using tissue culture for propagation of potatoes, developed through State aid.

Argentina has a history of producing enzymes of plants or animals by extractive methods, such as pancreatin, chemotripsin and natural renin. Production of microbial enzymes began only in the early 1980s through a joint venture called Milar, between Miles, a United States corporation, and Arcor, a local food industry firm. Milar produces microbial enzymes for the food sector. Argentina is the only Latin American country which produces isoglucose or fructose. Five plants, including one of Arcor's, have been set up for this purpose.

The pharmaceutical sector in Argentina is characterized by the presence of TNCs, but some local firms in this field are moving into biotechnology. The Poly-Chaco firm of Argentina is involved in diagnostic reagents. Institute Sidus, S.A., which was converted to Biosidus, S.A. in 1985, is engaged on production of medical and biological substances basically by biotech methods and genetic engineering, including human insulin and monoclonal antibodies. Biosidus also plans to develop DNA probes for detecting viruses responsbile for sexually-transmitted diseases, respiratory viruses and infant diarrhoea.

Argentina suffers from similar problems in the development of biotechnology as do most of its Latin American neighbours. Industry in Argentina mainly uses foreign technology and there is little industry-supported research. There are a number of small, fragmented laboratories (INTI has about 40), with allocation of a large percentage of the budget to salaries (65 per cent for INTI), and relative isolation from basic scientific research. However, INTI laboratories are fairly well-equipped and it has approximately 500 scientists, but its operating funds are limited.

Argentina's potato industry is a success story from the viewpoint of achieving domestic self-sufficiency. 34/ Five firms concentrated on micropropagation of potatoes. In 1980, Argentina imported approximately $640 million of potato seed. By 1985, less than $1,000 of potato seeds were imported.

Biotechnology in Argentina is viewed mainly as a method of competing at lower costs, especially in vaccines, biologicals and diagnostics. At the same time, a fairly effective base has been developed for biotechnology, particularly in agriculture and livestock but also increasingly in pharmaceuticals.

Cuba

In the 1980s, biotechnology was accorded considerable priority in Cuba. The major institutions in Cuba involved in biotechnology include the Centre for Genetic Engineering and Biotechnology (CIGB), the National Centre for Scientific Research, the Immunoassay Centre, and the Centre for Biological Research (CIB). Activities of the institutions include development of diagnostic methods using monoclonal antibodies for hepatitis B, production of hepatitis B vaccine using recombinant DNA, production of a meningitis B vaccine, development of a diagnostic technique for AIDS, and production of inputs needed for recombinant DNA technology. 35/ A government agency known as the "Biological Front" was created in the 1980s in an effort to link all institutions engaged in biotechnology.

Much of Cuba's scientific staff was trained at the National Centre for Scientific Research (CENIC), where research is concentrated on public health, drug synthesis, environmental science and corrosion research. New biotech methods are employed where possible. The Centre for Biological Research (CIB) was set up in 1981 to supply Cuban doctors with interferon for testing against cancer and viral diseases. CIB promoted cloning, expressing and producing of alpha and gamma interferons by recombinant methods. CIB is also involved in the training of personnel from other institutions. Financing will continue to come mainly from the Government, besides international sources. In 1983, it was decided to build a larger centre and the Centro de Ingenieria Genetica y Biotechnologia (CIGB) was established in 1986. Lines of research at CIGB include proteins and hormones, vaccines and diagnostics, energy and biomass, plants and fertilisers, cloning, expression and cell genetics. The educational system has strongly contributed to Cuba's biotechnology capability. Many researchers have been trained in the Soviet Union, besides United Kingdom, France, and Mexico. There is informal collaboration with foreign scientists, including through a North America-Cuban Scientific Exchange. All programmes, institutions and universities are government-operated.

Cuba has placed strong emphasis on health care and has stressed pharmaceuticals and human health in its biotech research, besides sugar cane research. The country has over 40,000 researchers and scientific staff. Research spending in 1986 was $165 million, more than one per cent of the national budget. Programmes include animal vaccines, interferon, biomass conversion, and high-protein food additives. In the agricultural sector, Cuba recently cloned the gene of the microorganism which causes red water fever in cattle. Plant biotechnology is also a national priority, and a major area of research at CNIC, largely on sugar cane. This is the most important crop in Cuba and various biotech methods are being used to improve and use it more efficiently. One method used is somaclonal variation to produce new varieties, where the hormones of plants are genetically manipulated so they will exhibit new genetic properties. 37/ Somaclonal variation has produced five varieties which are resistant to eye spot disease. Other agricultural research concentrates on improving amino acid composition of yeast for animal feed, ways of using waste from sugar refining (biogas) and characterization of active substances in plants. In health and pharmaceuticals, Cuba is a major producer of human-derived interferon and MediCuba, a State-owned pharmaceutical firm, is marketing several forms of interferon. 38/

The Centre for Biological Research has diversified considerably and has laboratories for *in vitro* gene manipulation, DNA sequencing, enzyme purification, oligonucleotide and peptide synthesis, monoclonal antibodies, and a computer facility. It is also engaged in vaccine development, fermentation and cell culture, energy and biomass utilization, food production, genetics and plant biotechnology. About half of its operation is, however, concentrated on the production of human interferon. Its achievements include regular production of human leucocyte interferon for clinical use, production of beta interferon for research, the cloning and expression of the alpha-2 interferon gene and the beta interferon gene in *E. coli*, the development of the ELISA system and the production of several restriction enzymes for genetic engineering. 39/

In 1987, Cuba announced plans to market an ultra micro-ELISA system designed for use in mass diagnostic programmes. Currently, ten pediatric hospitals have the complete system in Cuba. The Meningococcal Research Center in Havana also developed a possible vaccine against Group B meningococci, in 1987. The development of monoclonal antibodies for human health care has been given priority.

Some of Cuba's technological achievements in biotechnology, such as the cloning and expression of alpha-2 interferon, are impressive and Cuba's programmes on human health and agriculture, particularly production of interferon and improvement of the sugar cane crop, have been quite successful. Overall, Cuba's national policies and programmes are well-integrated, with a sound infrastructure for achieving policy goals.

Nigeria

Biotechnology is still in its initial stage in Nigeria. There have been some biotech research efforts in food science, textiles, pulp and paper, and pharmaceuticals. It was only in 1987 that a National Centre of Genetic Resources and Biotechnology (OGRB) was established in Ibadan. Through government efforts, problems regarding adequate funding and equipment, and shortage of qualified personnel in the field are being resolved. 40/

A major research institute in Nigeria is the National Institute for Medical Research (NIMR), set up in 1976. Its main task is biomedical research on the numerous health problems of Nigeria. NIMR works with the universities and teaching hospitals to train biomedical scientists and has a direct relationship with seven other centres throughout Nigeria. The Institute's research programmes focus on communicable diseases, environmental and community health, metabolic diseases, clinical science research, traditional medicine, and genetic engineering and biotechnology. In 1985 these were, however, only 19 scientists at NIMR in addition to technical and other staff. There are two international research institutes in Nigeria for biotechnology. There are the International Institute for Tropical Agriculture (IITA), and the West African Sorghum Programme, which have been particularly active in improved crop varieties. One of the major areas of research at IITA is to increase genetic diversity for plant breeding. Some success in this has been achieved in rice, cowpeas, yams and soya beans.

Nigeria's national goals and priorities for genetic engineering and biotechnology in the human health sector are vaccine production against endemic diseases, early diagnosis of inherited diseases such as sickle cell anaemia, classification of pathogens and their epidemiology, knowledge of drugs and biologically-active substances biological control of important vectors through gene manipulation, and the preservation of biological diversity. In the agricultural sector, Nigeria seeks to intensify production. Five priority areas have been defined: host-parasite interaction in plants, gene manipulation of plant cells for nitrogen fixation, host-parasite relations in animals, gene selection for describable traits in animals, and vaccine production against animal diseases. Nigeria is also trying for national self-sufficiency in wheat. In the industrial sector, the main priorities are for enzyme production, fermentation technology, production of preservatives and oils, and biological waste treatment. 41/

Funding for individual projects may be obtained at the Institute level, with the Government fully funding university research. The Ministry of Education administers funding and defines policies for Nigerian universities. The largest allocations in 1988 went to the Nigerian Institute for Oil Palm Research, followed by the National Cereal Research Institute, the Institute for Agricultural Research and the National Veterinary Research Institute. The total funding was N92.6 million, or around US$ 18.5 million.

In the agricultural sector, research efforts are focused on crop production, livestock and animal health, forestry, fisheries and crop storage. The major achievement is in the production of seeds for higher-yield, disease-resistant crops. Genetic engineering techniques are not used at present. The International Institute of Tropical Agriculture (IITA) and the National Root Crop Research Institute at Umudike have been able, through hybridization, to develop high-yield rice, and cassava seedlings.

Food processing is an area in which there have been some significant R&D achievements at the Federal Institute of Industrial Research (FIIRO), such as in wine production from local fruits, beer and bread. In addition, there is some private biotechnology research in this area, as well as at universities. FIIRO has made considerable efforts to transfer its findings to the public.

About ten of the 24 government research institutes are involved in biotech-related research, largely in agriculture and food processing. Genetic engineering is being applied to deriving improved varieties of yams, improving the shelf-life of palm wines and developing strains of wheat which are more suited to the climate. Little headway has been made in research involving biotechnology in the pharmaceutical sector. The establishment of a national research centre for pharmaceuticals took place only in 1987.

In comparison with other African developing countries, there is a relatively high level of skills in biotech research in Nigeria, with over 50 per cent of all of Africa's scientific and technical manpower. The nature of research institutes and activities in Nigeria also indicate government recognition of the importance of biotechnology. The main fields which need to be addressed are manpower training, strengthening of infrastructure for biotechnology, access to international information, an enhanced role for the private sector, and the supply of equipment and research materials. The major problem confronting biotechnology in Nigeria, however, is adequate funding. For this reason it is necessary to mobilize the private sector to make financial investments in biotechnology.

Efforts in biotech research are gradually being developed in Nigeria. There are several constraints but a good beginning has been made. With growing awareness of the potential of biotechnology, Nigeria and other African countries are likely to accord even greater emphasis and priority to biotechnology during the 1990s.

Conclusion

Efforts to build national capacity in biotechnology in developing countries at an accelerated pace developed only during the decade of the 1980s. There is still a wide gap between plans on paper and programmes actually implemented and a concerted effort needs to be made to ensure that these programmes do in fact contribute significantly to achievement of their objectives. The formulation of specific programme components also tends to be too ambitious for the resources, available financial and human. There has been inadequate commitment of resources, especially financial, to the programmes that have been prescribed. There has also been a reluctance to establish specific targets. There has also been a tendency to follow biotech research priorities that are popular in industrialized countries. This leads to efforts which may be less relevant to the urgent socio-economic needs of developing countries concerned. Also crucial is the continuing drain of some of the best scientific talents in biotechnology from developing countries to major R&D centres in industrialized countries. The phenomenon of privatization of not only commercial development but also supporting scientific work renders the task of the developing countries more difficult. At the same time, the experience of the developing countries discussed above demonstrates that a sound and effective beginning has been made, which can result in much more rapid growth in biotechnology in these countries in the future.

There also appears to be need for greater co-ordination among international agencies and development institutions concerned with the promotion of biotechnology and genetic engineering. The tendency to insist on an identifiable programme activity with which a particular agency is linked leads to considerable duplication and inadequate utilization of scarce human and other resources.

During the 1990s, it is expected that the possibilities for potential economic and social benefit from biotechnology will become much greater. It is vital that these lessons from the 1980s be taken into account in the ongoing endeavour to develop capability in biotechnology in developing countries in order that the potential benefits from biotechnology can be utilized to the maximum extent in developing countries.

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CHAPTER VIII

ADVANCED NEW MATERIALS

Technological developments in material sciences are likely to have growing impact in several industrial sectors. It has become possible, through advanced mathematical modelling, computers and advanced instrumentation to develop much greater understanding of the structure and properties of matter and even to rearrange the microstructure of materials so as to attain required properties. 1/ Such advances in materials designs imply a greatly accelerated rate in materials and related product innovation, and obsolescence of existing materials for various uses, besides reduced life-cycles for new materials. The materials field is undergoing a revolution with the emergence of advanced materials engineered without the constraints of thermodynamic equilibrium to meet specific needs. These materials can now be tailored to meet specific property or performance targets.

Materials science has become an interdisciplinary science requiring inputs from solid state physics, chemistry, metallurgy, ceramics, composites, mathematics, computer science and engineering. Materials and product design now require simultaneous teamwork across several fields. Materials scientists also are increasingly involved in the processing and fabrication stages of production. The design and processing of a material must be integrated with the design and manufacturing process planning of the end user. Materials design, component and/or product design engineering and manufacture are merging and require close integration and interaction between materials producers and users. New advanced materials may require the redesign of the end product and production process in order to take full advantage of the materials' properties. Advanced materials are, however, far more expensive than conventional materials and most advanced materials systems are presently developed for high technology sectors where performance requirements override cost considerations. Technical advances in high-technology industries, such as computers and electronics, aerospace, nuclear energy, high-temperature processes and biotechnology, are often constrained from the materials side. Such industries are placing increasingly stringent requirements on materials properties and performance. At the same time, there are significant developments of new electronic, magnetic, optical and chemical materials and devices engineered at the molecular level, which will have impact in several fields.

The early incorporation of such materials into new products and processes leads to improved competitive position. It also ensures international competitive advantage in industries incorporating new materials. Advanced materials can have considerable impact on global location of industry and trade flows in future. Advanced materials have, in some cases, been developed in order to eliminate import dependence of developed countries on imports of strategic and critical minerals. Import dependence may shift to strategic advanced materials components and raw materials entering the production of such components. Metals and chemical companies are reassessing their strategies and have begun a transformation towards becoming high-technology materials companies. There has been a marked and increasing tendency for forward integration by materials producers and backward integration by materials users. However, smaller companies can specialize and serve special niche markets.

The vast research and technical requirements of materials science has led to consortia between industry, government and universities in several developed countries. Governmental support is provided through provision for military research, development of standards and testing, provision of lab facilities and highly-advanced instrumentation for industry's use, and national co-ordination of materials research. 2/

Changing industrial structure

Several branches of manufacture in industrialized countries are currently undergoing considerable restructuring accompanied by a transformation of production technologies, management practices and patterns of organization because of increased application of microelectronics. It is within this changing structure that advanced materials will increasingly diffuse within manufacturing industry. Developments in various high-technology sectors are currently constrained by required improvements on the materials front. In so far as solutions are being found, further impetus will be given towards the technological and scientific transformation of industry. The advanced materials sector itself, however, must be viewed as a major new technology which can potentially transform the technological base of several industries. As such, it may prove to be of similar importance as the microelectronics revolution. Advanced materials will alter the global division of industrial labour including the location of mining and processing activities and seriously affect some resource-based industries in the long run.

At the same time, it must be stressed that new materials are currently coming up against severe processing constraints. They are produced in small volume, with high cost fabricating processes. Unless new, improved, high-volume processing techniques can be developed, most of these materials will be limited to very specialized applications, such as aerospace and defence. Nevertheless, materials research is actively pursued by many Governments, universities and corporations and is bound to yield commercial processing techniques to back up new materials design.

The establishment of various measures and standards for measurement and performance evaluation is required concurrently with, or even in advance of, the appearance of these new materials in commercial technology. The achievement of long years of experience before any need for standards is not possible for advanced materials. Furthermore, advanced technology and materials on which it depends are increasingly international. A new, broadly based, international effort is thus essential to assure that the prerequisite measurement base is in place as the development of new standards becomes necessary.

Advanced metals

Advanced metal alloys are now generated by introducing desirable properties in terms of conductivity, low brittleness, and performance at high temperature vibration and corrosive environments such as in aircraft engine applications. 3/ In fact, most research and development of advanced metals has been guided by the increasingly stringent requirements for high temperature performance as producers aim at higher energy efficiency. New alloy developments 4/ and new advanced processing techniques for cost-competitive metal production have also responded to demands for higher performance materials from most other industries, such as oil companies drilling in deeper, difficult environments, and the chemical processing industry's search for improved process efficiency and corrosion resistance.

Technological developments in advanced metals would inevitably have impact on demand for existing metals and minerals. World economic forecasts for the consumption of metals over the next few decades indicate relatively low rates for metals such as iron, copper, tin and lead. These rates will vary between 1 per cent and 3 per cent. On the other hand, consumption of metals such as aluminium, chromium and nickel, as well as those used in the manufacture of special steels, is likely to increase at rates above 3 per cent or 4 per cent, particularly certain metals which are widely used in high technology fields, such as columbium, titanium and gallium, where the rates will be in excess of 5 per cent. 5/ The industrialization of developing countries will further support the consumption of traditional minerals and metals, though the spread of new technologies will probably reduce the advantage of traditional metals as compared to the benefits gained by industrialized countries at earlier stages of development.

Advances in steel

Amongst new processes introduced to meet greater microstructural control and international competitiveness are new vacuum melting and degassing techniques. These were limited to stainless steels and aerospace alloys but have now been extended to carbon and alloy steels, continuous casting, controlled rolling and other thermo-mechanical treatments that reduce costs through reducing traditional heat treatment. HSLA steels are sophisticated mass produced materials that are used in the construction of large structures such as ships, oil platforms and cranes. HSLA steels provide opportunities for developing countries with existing or planned steel capacity. 6/ This could result in effective utilization of existing equipment capacity; added value for production; upgrading of local engineering standards; import substitution of costly heat-treated alloy steels; and improved competitiveness in world export markets.

Superalloys

Advanced metals have generally been aimed at high-temperature applications under extreme conditions. Superalloys are nickel-based materials developed for just such uses. Superalloys have greatly assisted in modern high-temperature engineering and form essential components of gas turbines that power jet aeroplanes.

Advanced ceramics

Advanced ceramics comprise a large number of materials deriving from the oxides, nitrides and carbides of silicon, aluminium, titanium and zirconium, which are processed or consolidated at high temperatures. These inorganic and non-metallic advanced materials have been developed in the last 10-12 years in response to needs arising from specific industrial and high-technology applications. 7/ Advanced ceramics have widespread applications, and seven broad groups can be identified: (a) electronics: advanced ceramics are used in integrated circuit (IC) packages, capacitors and resistors and in integrated optics, and have enormous potential in the high growth market of electronic components; (b) engines: an important structural application of advanced ceramics in the form of silicon nitride, silicon carbide and zirconium is in gas turbines, diesel and gasoline engines; (c) cutting tools and machine parts: existing cutting tools are reaching their limits with the need to use tougher, new alloyed metals. Tools made from advanced ceramics are showing distinct advantages over metallic counterparts, facilitating higher speed, reduction of costs and enhanced productivity gains; (d) industrial products: their resistance to corrosion and erosion has enabled new applications in the metals industries, chemical processing, oil and gas industries and precision jigs in the manufacture of electronic components; (e) consumer products: commercial application currently in use, especially in Japan, include sporting equipment, scissors, knives, etc.; (f) energy: applications include batteries, fuel cells, solar collectors, etc.; (g) space, aerospace and defence: heatshields and tiles for space missions and re-entry vehicles, infrared window, radomes, armour, military engines, etc.

Advanced ceramics possess properties that make them superior in many demanding high-temperature, high-stress, corrosive applications which subject materials to intense wear and heat. They can be lighter than metals, thus offering energy saving potential. Their use may also offer cost advantages to the user industry through process and product redesign. Advanced ceramics and composites could be viewed as structures rather than materials. Overall costs, taking into account integrated design, fabrication, installation and life-cycle, would render advanced ceramics competitive with conventional materials and metals in a large number of applications.

The synthesis of structural ceramics like silicon carbide and silicon nitride, and composties like aluminium-silicon carbide and aluminium-graphite can eliminate the need of special metals which are in short supply in many countries. Greater emphasis is needed on these ceramics and composites, particularly to decrease their costs of production and increase their performance, especially in regard to toughness. With respect to advanced ceramics, developing countries are far behind. Materials research and applications in these countries should aim at entering the field of advanced ceramics and composites without necessarily going through the cycle of high performance alloys. The need to develop inexpensive membranes and filters of ceramics, composites and polymers to purify and desalinate water is also an important requirement in several developing countries and deserves attention.

Engineering plastics

Polymers are organically-derived and synthesized materials that can be moulded at high temperatures and retain their shape when cooled. 8/ Plastics such as polyethylene, polystyrene and polyvinyl chlorine have been the mainstay of a large and growing plastics industry since the 1930s and are high-volume, low-cost-per-unit materials in contrast to engineering polymers or plastics which are of recent origin and are low-volume output and high-unit value.

Composite materials

Composite materials may constitute the fastest growing new materials. Two aspects of advanced composite materials require to be emphasized. The first is the use of such materials as natural selection where extreme performance requirements cannot be met individually by monolithic materials. Second, as they can be tailored to meet specific needs and conditions, they will become major structural materials of the future, displacing monolithic materials from many applications. Composites are synergistic combinations of materials so as to take advantage of the enhancement properties of fibres. For this, materials designers simply embed the fibres in a matrix of another material, so that the latter binds and protects the former. The reinforcing material contributes the main characteristics in terms of strength and stiffness but the matrix also affects properties such as heat and electricity conductivity. The combination of fibres and matrix govern the properties of behaviour.

At present, there is considerable international activity to translate the recent significant discovery of new high-temperature superconductors (HTS) into practical commercial applications (Table VIII.1). It is recognized that the new family of superconducting materials has revolutionary technological implications, and may constitute the basis for a new age of technology. However, before superconductors can have wide technological impact, they face considerable barriers in terms of processing and bulk production capabilities. These must first be produced commercially into useful forms such as thick and thin films, wire, tape and bulk materials. 9/ The development of such fabrication and processing technologies may, in fact, require new technologies as radical as the invention of the new superconducting materials.

The phenomenon of superconductivity entails the disappearance of electrical resistance as a material is cooled below some critical temperature. The critical temperature is that temperature at which the material's resistivity abruptly changes from a state of normal electrical resistivity to a superconducting state. Until the end of 1986, superconductivity was mainly connected with the properties of metals. It was only in February 1987 that a new ceramic superconductor was discovered. Currently conventional, commercially important, low-temperature, liquid helium-based superconductors, for example, columbrium alloys, have a $300 million world market in instrumentation and medical diagnostics (magnetic resonance imaging), with electronic components being a small part of the total market. Other estimates including the future market potential for superconductors are given in Table VIII.1.

In some developing countries, this could become an integral part of national science and technology infrastructure, including microelectronics and other advanced materials technologies, such as fine ceramics. In the medium term, the greatest gains are likely to be found in limited applications of high-temperature superconductivity, especially in various industrial machines and electronic devices. In the long run, potential gains of interest to developing countries would include magnetic levitation trains, electric generation and, importantly, the ability to store massive amounts of electric energy with no energy loss, medical diagnostics (magnetic resonance imaging) and geophysical exploration.

International competitiveness

Traditional materials are reaching their limits in many applications and it is the need for new materials in aerospace and military applications that has encouraged research into new advanced materials. Another important research determinant is the effort to reduce dependence on specific strategic and critical minerals such as cobalt, chromium, manganese and tungsten, in military and high-technology applications. It is superior performance rather than cost or import vulnerability that is sought in these high-tech applications, in which materials supplies have carved out specific niche markets prior to more generalized applications.

Advanced materials are largely utilized at present in high-technology growth sectors, such as aerospace, telecommunications, electronics, computers, biotechnology and automobiles. It is in these sectors that advanced materials find natural applications for their superior performance characteristics. Superior materials enter as intermediate inputs in such complex products as aircraft, microelectronic devices and cars and are vital to their functioning. Hence product and process innovation, international competitiveness and growth of key high technology sectors depend to an essential extent on the availability of appropriate advanced materials. Developments in materials science and engineering will, in fact, set ultimate limits or offer enabling conditions for growth and innovation, in technologically advanced sectors and other industrial branches.

By their very nature as intermediate inputs, advanced materials can enter virtually every production process and emerging products. As such they contain the seeds for potentially reorganizing several fields of production, inter-firm and inter-branch relationships, the economy-wide allocation of labour and distribution of skills, and the competitiveness and growth of individual sectors.

Developing countries will need to be increasingly integrated in the world economy. However, the large fixed capital in installed capacity in various fields may be subject to rapid product and process obsolescence, without endogenous capacity to respond technologically to changes in materials. The role of enterprises dominating specialty fabricating and advanced materials production in developed countries may become increasingly important. Whether developing countries remain in primary and processing activities or not, their industrial base will need to function and survive in a global market increasingly dominated by microelectronics-based technologies and advanced materials incorporated in both processes and products and subject to rapid change.

The research and development costs of new materials and the scientific and engineering, expertise in design, manufacturing and testing is beyond the means of most small companies. Materials production in the future is likely to be dominated by large, integrated, research-intensive TNCs. Indeed, another major feature of the global corporate environment in materials is the growing internationalization, mergers and acquisitions, licensing agreements and joint ventures. Another major trend and characteristic is the massive support programmes for new advanced materials research provided by Governments in the United States, Japan, European Economic Community and individual European countries. Governments are providing military markets, research grants, research laboratories, and co-ordination of industry and university research efforts. However, enhanced industry and government research efforts in the development of new materials is not enough to create or preserve competitive advantage in commercialization. What is required is that an appropriate technological infrastructure is in place for quick development and commercialization of the results of research.

Policy issues for developing countries

Different developing countries are in different stages of development and materials cycle and presently represent a spectrum of requirements as well as capabilities to deal with the new materials revolution. In view of this, uniform prescriptions cannot be applied for all developing countries. The first and foremost response of developing countries should be to establish mechanisms to monitor the most significant developments such as, for example, high-temperature superconducting materials at the earliest possible stages. These emerging developments can be monitored through mechanisms of technology forecasting, followed by technology assessments from the viewpoint of individual countries to determine the priorities of action in the light of such developments.

Materials processing needs to be channelled in directions of materials, components and low-energy consuming processes which can generate employment in developing countries. Computer-aided design and simulation should be used to reduce redundant factors of safety in order that smaller quantities of materials are adequate. The information input for materials processing should be as much as possible, but the actual process should be technologically simple so that it can be utilized in developing countries at various stages of development. In the context of development needs, materials should be made as far as possible using local resources and manpower, and relatively simple technologies. It may be worthwhile to upgrade certain traditional materials and processes. A trend in materials technology, namely, parts consolidation, leading to fewer parts resulting from single step moulding of complex shapes, could also be very important.

Many of the knowledge-driven advances in materials science can and should be channeled towards development needs. These include rapidly solidified structures, macro molecular materials plasma, sprayed and vapour-deposited materials, mechanically alloyed materials, materials which have three-dimensional structure architecture, materials with controlled interfaces made from super ultrafine powders where the bulk properties do not remain valid, and surface processed materials.

Housing remains one of the most important problems of development due to lack of availability of materials and this is an area where miniaturization cannot be applied beyond a certain point. 10/ One of the major challenges is reduction in the cost of materials for housing and increase in the performance of construction materials, particularly those based on local, renewable or abundant resources. The main priorities here will include greater attention to materials science and technology of alumino silicates, earth, stone, laterite and clay-based products which are available or can be made in most countries. There is also need to improve the performance of bricks from common clay and develop biomass or solar energy sources to fire them, or to develop low temperature binders and sintering agents. Research in genetic engineering and in bioprocessing of materials would be useful to increase the strength of wood and fibres available from fast-growing trees, in addition to the present focus on increasing the yield. The development of plants which can get nitrogen from air will considerably reduce pressure for manufacturing fertilizers from minerals in developing countries.

It is also important for developing countries to ensure improvements in materials-related technologies through the establishment of neutral and capable institutions for materials testing and quality control. It would also be necessary to develop the existing infrastructure in teaching and research institutions and relate these to national facilities for testing of materials. At the same time, higher education and specialized training programmes should be developed for material scientists and researchers and engineers with multidisciplinary backgrounds. Industry-university collaboration must be encouraged, including through governmental incentives so that universities define basic research agendas for solving materials problems and, in the process, train and educate materials scientists and engineers with such multi-disciplinary backgrounds and skills the industry most urgently requires. Financing methods can be tied to contractual, co-ordinated and long-term research and development programmes in this field.

Materials centres in developing countries can, through national and international efforts, promote co-operation between disciplines and between laboratories and can develop into specialized institutions in specific fields. The question of whether a materials-related centre of excellence is beneficial depends on the circumstances involved. The centre concept can be most beneficial if it provides a mechanism for several parts of the technical infrastructure to come together, so that the centre's activities amount to more than the sum of its parts. In most developing countries, science and technology are widely separated in different types of institutions, and combining some of their components in a common endeavour can be of great advantage. If industrial inputs are also factored in, the research and development efforts should lead to developments impacting on industrial manufacture. In addition, the training of students and research scientists can often be combined in such an endeavour.

Setting up centres of excellence may enable developing countries to benefit from the new opportunities that are opening up. In industrialized countries, for example the United States, several centres of excellence in materials science have been set up in the last ten years. Among developing countries, India has some experience in setting up such materials centres in universities. These have been set up in the form of materials research laboratories in universities which already have programmes in materials science. In addition to these materials laboratories, engineering research centres have been funded including, for example, centres for composites materials and ceramics. 11/

Policies require a "critical mass" in order to be effective. Most laboratories in developing countries have neither size nor materials resources necessary to undertake effective research and development in new materials. The national research and development potential is often limited. The restricted size of potential markets for new materials has implications for technological development and hence for R&D. Despite these obvious constraints, efforts have to be made to develop knowledge and capability in materials science in developing countries. Apart from technology monitoring and national research efforts in materials science, new materials technologies should also be sought to be obtained through alternative channels of technology transfer, 12/ including (a) licensing of new materials technologies; (b) joint ventures with proprietors of such technologies or (c) purchase of specific materials technologies or of companies engaged in materials research in specific fields.

Developing economies need to examine carefully the need and potential gains from a strategy of "make some and buy some" in terms of relative emphasis on national materials research or on promotion of joint ventures and licensing agreements for the production of ceramics, and metal or polymer matrix composites with large TNCs or smaller specialized companies aiming at niche markets in industrialized countries. Both these approaches are necessary in the context of a national technology and industry strategy. Primary producers need to study the degree and forms of government support by industrialized countries and co-ordination activities and developments in materials research and development. The role of the Government in supporting and co-ordinating private sector and university as well as State-owned or supported research institutes and laboratories engaged in materials research, acquires added significance in the context of a developing economy in the 1990s. It is essential that developing countries begin to develop long-run capacity to absorb, analyse and respond to successive innovations in materials technology that threatens their competitive position. There must be a cumulative build-up of a domestic scientific, technological and industrial base to provide the necessary skills for a real response at the level of materials technology.

It may also be possible for certain developing countries to set up materials science and engineering centres manned with appropriate multi-disciplinary teams and funding, which could conduct research on specific materials or engage in broader research in materials science and engineering. Regional co-operation also offers great opportunities in terms of collaborative efforts in education and training, pooling and co-ordination of R&D expenditure, linking of national scientific and professional societies, and the establishment of regional centres for materials science and engineering for more effectively bringing together several interdisciplinary teams engaged in pure and applied materials research.

New technological developments in materials will undoubtedly have impact on almost all countries. The changing pattern of raw material consumption will affect mainly developing economies which are active in extraction of natural resources. Developing countries with established traditional ceramics will also be faced with changing markets, especially in the case of refractories. At the same time, since sophisticated technologies and materials promise profitable ventures, there will be growing demand for co-operation with developing countries in order to enjoy comparative advantages, particularly cheaper labour and lower research costs in these countries. There will also be growing effective local demand in these countries for new materials that will economically substitute for traditional materials, including building materials, light-weight composites, building materials composed of non-metallics, and biomass.

Notes and references

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10/ P. Rohatgi, "Current Revolution in New Materials: Opportunities for the Developing World", UNIDO unsymbolized document, April 1988.

11/ ibid.

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Table VIII.1

World markets for superconductors

(Million US dollars)

Industry	1987	1992	1997	2002
Integrated circuits	25	75	225	400
Laboratory instruments and sensors	45	25	500	200
Medical diagnostics	150	300	150	750
High energy physics	25	150	20	200
Electrical power	5	10	5	40
Transportation	-	45		
Magnetic separation	5	25	60	175
Total	215	586	1,085	1,775

Source: Advanced Ceramic Materials, vol.3 No.1, 1988 based on a "High-Tech materials alert" report.

CHAPTER IX

POLICY ISSUES FOR DEVELOPING COUNTRIES

Technological developments and their impact and potential for developing countries necessitate a well-defined set of policies and institutional arrangements. Existing institutions in these countries relate primarily to science education and local research in certain fields and to regulation of foreign technology agreements in some developing countries. Several other policy aspects also need to be considered. These range from human resource development to channeling TNC investments and technology transfer in new technologies. It would also be necessary to ensure changes in industrial methods and management. Technology assessment and forecasting will also need to be undertaken.

It is necessary that comprehensive technology plans are drawn up in each country. These should be based on an assessment of the implications of new technologies in the principal production, service and trade sectors in each economy. Such plans should include the development of technological infrastructure and should be wholly complementary to sectoral plans and programmes in principal sectors of each economy. It would be necessary to identify technological needs of such sectors in relation to the implications and potential of microelectronics developments and biotechnology. Such technological needs should be assessed with respect to global competitive capability, particularly in export sectors. It is also essential to develop suitable technological infrastructure, particularly with respect to information and specialized skills and services. Technology information systems need to be developed together with increased local capability in technological services. Policy parameters should be defined for inflow of foreign investment and technology in new fields and measures undertaken for technological absorption and adaptation. Continuing technology assesmnent, monitoring and forecasting will also be necessary. These elements will obviously vary in their importance from country to country. Technology planning must, however, be viewed as a dynamic and continuing process, directly related to new technological developments and their implications for each economy.

Human resource developemnt is the most important aspect of technological infrastructure. For new technologies and new products, new categories of technical personnel must be trained in adequate numbers. Greater emphasis must be given to specialized training facilities for computer programmers and systems specialists, microbiologists and researchers in biotechnology and other categories. A time-bound programme, say for five years, for such specialized education and training should be prepared and directly related to the projected requirements of such personnel. Training programmes are also necessary for development of entrepreneurial and management capability related to new technologies. Developments in management technology are of major importance, and absorption of latest management techniques in use of numerically-controlled equipment, just-in-time operations and in achieving optimum production standards are most essential.

A critical need is for access to technological information. Such information is necessary on major technological trends in various fields and regarding alternative sources of technologies from TNCs and other enterprises. Information on costs and contractual aspects of use of specific new technologies and applications also need to be collected. For most standard technologies, alternative sources can generally be identified. For example, technology for production of microcomputers and peripheral equipment can be obtained from several sources and knowledge of such sources is very necessary. A national information system on science and technology in selected fields should be developed, which would have linkages with external data bases and sources of information on alternative technologies. A useful source among international organizations is the Industrial Technological Information Bank (INTIB) of UNIDO, Vienna, which can provide very useful data and material on industrial technologies and services.

It is also necessary to develop local capability for various technological services ranging from micro-level project identification and feasibility studies to engineering and plant design, commissioning, start-up and operations. There is considerable inadequacy in several countries with respect to local consulting services for certain of these functions, particularly design and engineering. The development of national consultancy firms to perform such functions should be encouraged.

It must be recognized that inflow of new technologies from foreign countries and enterprises will be essential for developing countries, both for new applications and production capability and for blending with traditional processes. Such inflow can take the form of direct foreign investments by TNCs or joint ventures with minority foreign holdings or through non-affiliate licensing. Transnational corporations will undoubtedly constitute an essential source of supply of new technologies in sectors such as microelectronics, biotechnology and new materials. The terms and conditions of their participation may, however, prove more difficult to negotiate. Unlike resource-based industries such as petroleum and minerals, there are less factor-resource advantages in knowledge-based new technologies, except cheap labour and local markets. As for labour wage differentials, this is becoming eroded because of increased automation. With respect to local markets, these still tend to be fairly limited, even in large developing countries. At the same time, the growing technological diffusion of new technologies will result in additional and alternative sources of technology in most fields. It will be necessary for developing countries to adjust their present policies on foreign investment and technology to ensure that effective TNC participation does take place in one or other form, ranging from TNC subsidiaries and affiliates to non-affiliate licensing. In certain technologies, the insistence on foreign minority holdings may need to be relaxed in the interests of inflow of new and emerging technology. With the growing number of foreign companies having access to such technologies, it should be possible to locate and select foreign companies for technological participation.

It is important that adequate inflow of suitable technology takes place in desired sectors and is transferred on suitable terms and conditions. The issue of appropriate technology has become increasingly complex with new technological innovations which can be applied on an intersectoral basis. Appropriateness must be judged in relation to the objectives and factor conditions in the country where it is utilized. The use of computer-aided designs for ready-made garments for exports to developed countries is quite appropriate, even in countries with relatively cheap labour. Similarly, the use of numerically-controlled machine tools, or even robots, may be quite appropriate for production of parts and components which require a high degree of accuracy and precision over sustained periods of time. The blending of new technologies with traditional sectors and production processes is also a critical aspect of technology choice. It is also necessary to relate technology choice to available local materials and skills.

It is important to select the most suitable source of new and emerging technology from the viewpoint of the nature of the technology, its use and application in the host country and the terms and conditions of foreign participation. For nationally-owned enterprises, it is necessary to search for suitable technology partners from among major TNCs in the field and other alternative sources that may be available. There is a growing tendency in developing countries, particularly in Asia, for joint ventures and non-affiliate licensing arrangements in preference to traditional subsidiaries of TNCs. In most developing countries, the appropriate investment structure and relationship with the TNC supplying technology and know-how would also largely depend on governmental policies on foreign direct investment and on the development of local entrepreneurial capability.

The contractual arrangements for technology acquisition may pose difficulties in certain developing countries. This is especially because there is a growing trend for privatization of new technologies through intellectual property rights, particularly patents and proprietary know-how in microelectronics and biotechnology, and copyrights on new computer software. The position on intellectual property rights on new technologies is still blurred and legislation on patents and copyrights should be reviewed so that national interests are protected. In recent years, considerable experience has been acquired in several developing countries on the intricacies of technology licensing and contracting, particularly where regulatory bodies have been set up, as in several countries in Latin America and Asia and in some African countries, to review foreign technology agreements in accordance with norms and guidelines.

Contract negotiations on new technologies may pose greater difficulty in negotiations. Royalty rates in computer software agreements may be different from the traditional percentage of net sales provided for more mature technologies. With respect to other terms and conditions, such as duration, warranty, access to improvements, export rights, tie-in conditions, training, governing law, settlement of disputes etc., contractual provisions relating to new technologies may present more difficulty, partly owing to the nature of new technologies and partly because their implications are often difficult to assess in different situations.

While several developing countries may continue to have technology regulation agencies, the role of such bodies needs to be more clearly defined in relation to new technologies. Technology regulation bodies need to view the inflow of foreign technology from a national viewpoint. Such technology, as is essential for a country's development, should be encouraged for acquisition and a flexible attitude needs to be adopted, particularly where new technologies and products are involved. At the same time, regulatory bodies have to ensure that licensee enterprises in these countries are not taken advantage of. A balance needs to be achieved between the need for foreign technology inflow and flexible norms and guidelines. It is also necessary to ensure effective technological absorption and adaptation. It is particularly necessary for national research institutions to shift their emphasis to applied research and to new technological applications, particularly technology blending.

New technologies, particularly informatics and biotechnology, necessitate a review of the structure of industry in most developing countries. Alternative export products may need to be identified or imports suitably scaled down. The nature of industrial restructuring would obviously vary from country to country. In countries where a fairly substantial level of industrial growth has been achieved, industrial structuring may largely take the form of technological upgrading of products and processes and the assimilation and adaptation of new technologies, particularly microelectronics, to production processes. This may require major adjustments in sectoral growth patterns and new investments on technology and equipment. Techniques, such as use of microprocessors, may necessitate new arrangements for collaboration with TNCs in order to acquire and absorb new technologies in different fields.

Changes in organizational and management structure, consequent on the use of new technologies, would also be necessary in most developing countries. The industrial success of certain South-East Asian countries has been, in large measure, due to adjustments in organization and management of industrial operations. The influence of Japanese management systems and techniques has been an important feature in most of these economies. Irrespective of the overall form of management, various aspects of industrial organization and management would require much greater attention.

It is of growing importance, at the national level, to assess and forecast the impact of new technological developments on national economies. The monitoring of technological change is also of critical importance in all developing countries and must be viewed as an integral element of national technology planning. It is only through assessment and forecasting that the implications of new technologies can be effectively monitored. For developing countries, technology assessment, monitoring and forecasting could provide valuable inputs for technology planning and management. Such assessment would need to be broader in scope than that in industrialized countries and should also cover the potential of new technologies in meeting technological objectives and priorities. Specific goals need to be defined regarding expansion of the scientific and technological base, the restructuring of the production system and the development of adaptive and innovative applications of new technological developments. Blending of microelectronics and biotechnology in traditional sectors and processes also provide major opportunities. Technology assessment at the national level should also provide an evaluation of different models and scenarios for development and alternative strategies for effective utilization, absorption and adaptation of new technologies. Despite inadequacies in information systems and data availability in most developing countries, technology assessment and forecasting can serve as a valuable tool for integrated technology planning and management. Different priorities would, however, apply in the case of large and populous countries than for small, landlocked countries or groups of relatively small- or medium-size countries at similar levels of socio-economic development.

New technological developments in particular sectors may be of special interest to particular countries or groups of countries. For export-oriented economies, as in South-East Asia, recent technological developments in automation and microelectronics may be of special importance. Similarly, countries exporting minerals and other commodities must assess the implications of new materials as in the case of gradual replacement of copper by optical fibres in communications. The wide variations among developing countries necessitates that technology assessment must be directly related to national situations and endowments.

Considerable experience of technology assessment and forecasting has taken place in certain developing countries. In the Republic of Korea, the Korean Institute of Science and Technology (KIST), as also the Advanced Institute (KAIST), undertook extensive studies to identify strategic or "champion" technologies. Malaysia utilizes technology assessment in its economic planning process. Varying degrees of technology assessment and forecasting are also implicit in the economic planning process of several developing countries, such as Brazil, China, India, Indonesia and others, particularly with respect to high-technology sectors such as microelectronics and biotechnology. More extensive use of the mechanisms of technology assessment is, however, necessary. It is also important that national expertise should be effectively mobilized in this process and that technology assessment studies are not limited to governmental departments and agencies. What is necessary is a fairly detailed assessment, at interdisciplinary level, of the impact and trends of new technologies and the implications and potential these may have on each developing country. This will involve collection and analysis of considerable qualitative material and quantitative data relating to usage and trends in new technologies, both at national level and in other countries. Such national studies should highlight the broad implications of new technologies and the range of technological options in various production and service sectors, as also the policies and programmes that may be required. Technology assessment should be viewed as a continuing process and constant monitoring and updating of technological trends and developments is essential.

Technology assessment is a comparatively new field and has been sought to be implemented through various mechanisms in different economies. In developing countries, the appropriate mechanism for such assessment may differ from country to country but the basic objective of assessing and forecasting new technological developments is of vital importance and should be effectively achieved in these countries, as also at regional and subregional levels. At the same time, production capability should be developed through substantial inflow, absorption and adaptation of new and emerging technologies.

It is obvious that, in most developing countries, various technologies will have to co-exist. At the same time, innovative applications will need to be extended at all levels, from large industrial enterprises to small rural communities. The concept of technology blending is a crucial element in the management of technological pluralism and involves varying levels of integration of new and emerging technologies with traditional economic activities. The basic rationale for technology blending is that, through applications of microelectronics, biotechnology and other new technological developments, traditional products, processes and techniques can be substantially upgraded, and their productivity and efficiency significantly increased. In developing countries, in particular, the introduction of new technologies that are integrated with traditional products and processes may have better prospects for local absorption, adaptation and innovation than entirely new technologies. There is also likely to be less resistance to the introduction of new technologies if they are not perceived as displacing traditional activities, but rather as contributing to greater productive efficiency. Potential integrated applications can be considered in various areas, such as using microelectronics for food storage, control on irrigation and moisture control, apart from usage in industrial sectors, and utilizing biotechnology for upgrading of traditional agricultural practices through nitrogen fixation, production of single cell proteins and achieving increased crop yields and desired properties through tissue culture.

The development of applied research capability must also be given greater emphasis in developing countries. The very large outlays on research in new technologies in developed countries cannot be emulated in developing countries. What is, however, possible is to link endogenous research to local technological applications through blending, as also to concentrate on new technologies directly related to local needs such as tissue culture, biomass energy and other such fields. It is also necessary to provide major incentives for enterprise-level research, including by TNC affiliates in new technologies and applications.

There should, therefore, be a well-defined framework of policies and programmes on new technologies in each country. Certain developing countries have already adopted specific policies on electronics or biotechnology. The framework of national policies can vary considerably, depending on a country's factor endowments, stage of technological development and socio-political structure. A comprehensive policy framework must necessarily deal with various aspects, extending from awareness and knowledge of global trends to the development of national capability for production, research and technological adaptation and innovation. With enormous variations in factor endowments and conditions, a suitable policy framework has to be structured within basic development strategies, including those of export promotion or import substitution or an effective mix of the two. It has also to be related to overall perspectives and policies on foreign direct investment and the role of TNCs and their affiliates in developing countries. It is obvious, however, that the technological infrastructure will need to be significantly developed and re-oriented to meet the needs of new technologies. The potential for specific applications of new technologies, including possibilities of blending, also requires to be determined, both in priority production sectors and to meet the requirements of rural regions and small-scale production activities. The approach towards TNC investments and foreign technology inflow should be well-defined and flexible and, at the same time, structured in such manner that TNCs can effectively contribute to the utilization of new technologies in local conditions.

International programmes designed to extend new technologies to developing countries can take various forms of inter-country co-operation between developing and developed countries and between developing countries. Such co-operation can range from greater exchange of information and experience and assessment of such technologies to commercial arrangements for equity participation and increased technology transfer between institutions and enterprises in different countries.

It is necessary that South-South co-operation should be maximized with respect to new technologies. A critical need is to develop information networks and linkages between developing countries. Information on country experiences need to be pooled, with a view to assessing the potential, as also the problems and hazards posed by new technologies. Closer linkages also need to be established between universities and research institutions in developing countries with respect to new technologies. Though such linkages are increasing, these are still very inadequate, particularly in the context of fast-growing information technologies. Measures for receiving, storing and disseminating scientific and technological information in developing countries need to be substantially improved and international programmes could significantly assist in this regard.

There is also considerable scope for extending technological knowledge and capability on new technologies which are available in the public domain in developed countries and in some developing countries. Though there is growing privatization of such technologies in industrialized economies, there is still considerable scope for transfer of scientific knowledge and technological applications available with government agencies, research institutions and public bodies in different countries. There is also substantial scope for increased commercial relationships between production enterprises in developing countries through technology transfer arrangements of various forms. This is still relatively limited with respect to new technologies. While such relationships would be primarily determined at enterprise level, government agencies in various developing countries can significantly assist in this process by defining, or re-defining, norms and guidelines for technology transfer and development among these countries in accordance with changing needs and priorities.

The role of international agencies, particularly of the United Nations Industrial Development Organization, with respect to new technologies should also be substantially enhanced and strengthened so that their activities can be catalytic for the development of national capability in this field.

ACRONYMS

AIDS	Acquired Immune Deficiency Syndrome
BKPM	Investment Co-ordinating Board
CAD	Computer-aided Design
CAT-scan	Computer Assisted Tomography scan
CATV	Community Antenna (Cable) TV
CMOS	Complementary Metal Oxide Semiconductor
DNA	Deoxyribonucleic Acid
rDNA	recombinant DNA
DPT vaccine	Diphtheria-Pertussis-Tetanus
DRAM	Dynamic random access memory
EEC	European Economic Community
ELISA	Enzyme-linked Immuno Sorbent Assay
FDI	Foreign Direct Investments
GDP	Gross Domestic Product
GNP	Gross National Product
HIV	Human Immuno-deficiency Virus
HSLA	High-strength Low Alloy Steels
ILO	International Labour Office
INAPI	Institut Algérien de Normalisation et de Propriété Industrielle
INPI	National Institute of Industrial Property
ISDN	Integrated Services Digital Network
NMOS	N-channel Metal Oxide Semiconductor
OECD	Organization for Economic Co-operation and Development
OTA	Office of Technology Assessment
UNCSTD	United Nations Conference on Science and Technology for Development
UNCTAD	United Nations Conference on Trade and Development
UNESCO	United Nations Educational, Scientific and Cultural Organization
WIPO	World Intellectual Property Organization