

Chapter 8

Technology Development and Transfer

8.1 Technology, the practical application of scientific and other technical skills and knowledge to the production, processing, distribution and utilisation of goods and services, is vital to economic growth and development. Technology development makes it possible to create entirely new processes, products and services, and to improve existing ones. It raises economic and social productivities, which increase standards of living, and it improves the factorial terms of trade, which enables countries to protect or enhance their international competitiveness in particular products or services. No one country can expect to be completely autonomous technologically, and because technologies can be transferred internationally, a country would not be using its resources optimally if it tried to do so. But all countries should aim to enhance their skills in acquiring technologies, and disseminating, absorbing and adapting them efficiently.

8.2 The gap in scientific and technological capacity between developing and developed countries is not only great but widening, as a result of the accelerating pace of technological change. It is vital that developing countries recognise the crucial need to enhance their ability to absorb, adapt and utilise technology, by reorienting their human resource development policies so that their workforces can contribute effectively to development and ensure that their countries' international competitive positions are maintained or improved.

8.3 In this chapter we consider the changing nature and scope of technological change, its impact on economic and social development, the need to develop technology policy to take account of this impact, and the desirability of improving the terms and conditions of technology

transfer to ensure that developing countries can benefit from the progress that has been made. The centrality of technology to development, its accelerating pace, complexity and pervasiveness, and the need for developing countries to develop and acquire it in the face of growing constraints, provide the rationale for including the issue in this Report.

Changing Nature and Scope

8.4 Technological innovation has progressed incrementally almost since time immemorial. But over the past two hundred years the process has gained momentum, often exhibiting wave-like patterns whose peaks have been associated with major innovations, derived from science and realised through entrepreneurship. Examples include the development of the steam-engine and the spinning jenny in the second half of the eighteenth century, and electricity and the internal combustion engine in the second half of the nineteenth. A more recent example is that of microelectronics. Since its commercialisation over twenty years ago, this technology has given rise to many innovations. The pace and scope of change have been such that discontinuities of historic dimensions are becoming visible in economic, social and political life to an extent that the future cannot confidently be extrapolated from the past.

8.5 We have noted the attention given by the Commonwealth in recent years to technological change and its management, and we acknowledge the major contribution made to thinking on this subject in 1985 when a working group under the Chairmanship of Prof M G K Menon compiled the Report "Technological Change: Enhancing the Benefits". As its title indicates, the Report took a positive approach to the subject. It recognised the great benefits which are being brought about by technological change and in its recommendations concentrated on ways which could enhance those benefits. We understand that as a result a Commonwealth Consultative Group on Technology Management has been set up to provide a better focus on an issue which will be of continuing importance.

8.6 While technological innovation has advanced on a broad front, that in microelectronics has been particularly pervasive. Its effects have been both distinct and synergetic. Microelectronics has transformed many products (often 'miniaturising' and making them capable of multiple functions); improved the control, efficiency, performance and flexibility both of products (such as word-processors and computer-numerically-controlled (CNC) machine tools), and of processes (such as computer-aided manufacture (CAM) and 'just-in-time' manufacturing based on computerised minimal inventory holding); and, most importantly, through computerisation, it has made possible the rapid handling of information of every kind. At the same time, the application of

microelectronics to other advanced technologies, such as biotechnology, lasers, new materials and renewable energy, has enhanced their effectiveness and extended their scope, while creating whole new clusters of technology, such as those in the fields of telecommunications, automated services (especially banking and other financial transactions), and advanced diagnostic, surgery, and healthcare procedures. Its application has similarly enhanced the qualities of more mature technologies.

8.7 Looking to the future, however, other new technologies are expected to have at least as great an impact. Biotechnology, although progressing at a slower pace than many envisaged in the early 1980s, has already been applied in a wide variety of areas. They include agriculture, where genetic engineering and cell manipulation can create desired animal and plant characteristics; healthcare, where recombinant DNA techniques can provide improved diagnostics, vaccines, antigens and other pharmaceuticals; energy, where alternative fuels can be made from biochemical feedstocks; and the environment, where pollution can be reduced and waste treated using microbial techniques. New materials, such as fibre-optics, special plastics, hardened ceramics and composite materials, have an equally wide range of applications, from construction, aeronautical and automotive engineering to medicine and dentistry. Comprised of man-made materials or of commonly available elements, they can be substituted for conventional materials. Where they replace scarcer finite resources such as metals or petroleum, this substitution can be generally beneficial, especially in the long term, but it can also destroy demand for a range of products on which many developing countries depend for their foreign exchange earnings.

8.8 The need to develop renewable energy technologies is even more manifest, to provide both for wider spatial distribution of energy sources in developing countries and for more environmentally benevolent forms of energy. The latter is especially important in view of current concerns over fossil fuel use and the greenhouse effect of global warming. Technologies to produce energy from such renewable sources as sunlight, wind, water and biomass have been developed, and are being improved. But while they have the potential to assist development in the rural areas of developing countries, they are expected to contribute only marginally to global energy consumption during the next couple of decades (and only up to some 15 per cent by the year 2025). On the other hand, energy conservation technologies, such as integrated heat and power systems and fluidised-bed combustion, are expected to contribute significantly to higher energy efficiency, and hence to reduced consumption of fossil fuel per unit of output. There is particular scope for increasing efficiency in energy use in those countries, such as in Eastern Europe and certain

of the newly industrialising countries, where a large proportion is used in heavy industry.

Economic and Social Impact

8.9 As with previous major innovations, the overall impact of micro-electronics and other advanced technologies on economic growth and development has been very positive. These technologies will continue to produce new goods and services—in some cases whole new industries—as well as foster international competitiveness in the countries adopting them. And as with previous experiences, we expect that over the longer term, increased demand for labour derived from higher economic growth and enhanced development will more than compensate for job losses arising from the use of labour-saving new technologies. But, in the short term, we acknowledge that the effects are likely to be negative for particular enterprises which have become uncompetitive, and for particular groups of workers whose skills have become redundant. In extreme cases, the effects can even be negative even for countries if they lack the capacity, or otherwise fail, to adopt new technologies vital to their economies. Restructuring and retraining are therefore crucial elements in the management of technological change, as is the building of indigenous technological capacity.

8.10 To the extent that industrial countries have adopted advanced technologies, their overall output and employment have increased and their international competitive positions have generally improved commensurately. In most of them the output of high value-added, high-skill industries employing advanced technologies has tended to rise faster than that of sectors based on more mature technologies; and within industry the movement has generally been in the same direction—away from heavy engineering and shipbuilding towards light engineering and electronic components, for example.

8.11 For countries which are economically less developed, technological change has usually been more difficult to accommodate and manage. Its impact has tended to be more disruptive, because of the lower capacities of these countries to absorb and adjust effectively to new technologies, and because their economies often lack diversity. Technologies which have led to a deterioration in the international competitiveness of a country's major export, for example, can have severe effects on employment and balance of payments, and pose major problems of economic management, which in some cases can be overwhelming. The danger has been intensified with the linked use of computers and telecommunications. This has largely globalised markets and made it very difficult for any country, developing as well as

developed, to be economically successful but remain outside the global economic system.

8.12 On the other hand, the growing internationalisation of production made possible by the use of new technologies can present new opportunities for developing countries, not only in traditional areas such as industrial sub-contracting and assembly, but in new ones such as data processing and software development. Moreover, the cost reduction in data generation, processing and transmission, as well as in telecommunications, is of benefit to all countries. Microelectronics has also given new life to small-scale industries with modest capital requirements and production processes often well attuned to the resource circumstances of the countries concerned. Biotechnology has the potential not only to reduce the cost of food and drugs in developing countries but also to stimulate indigenous development, for example tissue culture, which is not very demanding in terms of research resources, and to create new products (for example drugs tailor-made to tackle specific tropical diseases). In addition, the use of new technologies can increase the dissemination of information on, and the acquisition of knowledge of, a wide variety of functions or activities. And, crucially, the adoption of advanced industrial technologies can enable newly industrialising countries to leapfrog certain stages of the industrial development process. On the whole, therefore, the problem is not one of too much technological change, as of the need to have and share in it, the difficulty of managing it, and the widening gap in capabilities that is apparent between developed and developing countries, particularly the poorest which are in danger of technological marginalisation. The utilisation of the growing technological opportunities depends on the availability of a skilled labour force, capital and infrastructure, which are usually missing in the poorer countries, as well as on appropriate macro-economic and technology policies.

8.13 The impact of advanced technologies, particularly microelectronics, on employment skills is two-fold: on the one hand, they create greater demand for technical and managerial skills, but on the other, they can deskill jobs. The consequence is likely to be a deepening polarisation in the labour force: those workers conversant with new technologies secure higher paid, protected employment, while those without such skills are increasingly vulnerable and marginalised. (The same is true of countries.) Overall, technological change requires more and higher skills, not less. Those who wish to keep pace with it must commit themselves to much scientific and technical training, and in view of the foreshortening in innovation and production cycles, to continuous retraining as well (see paras.5.25-5.27 above).

8.14 New technologies have already begun to affect the organisation

of work, both within the workplace and in its spatial relationships. Within enterprises, former hierarchical structures are being replaced by more flexible group-based systems of operation. Spatially, information technology theoretically permits almost unlimited decentralisation of activities, ranging from administrative staff working from their own homes or from cheaper locations, to data processors working in one country and transmitting the results to another. (How far such movements will be constrained by social, security and other factors remains to be seen.) Information technology also has the potential to reduce urban congestion by means as different as home-working and computerised traffic control. And by reducing the need for business travel, through the use of fax machines, computer-video links and teleconferencing, it can in the longer term contribute to reducing energy consumption and thereby lessening pressures on the environment.

8.15 Most importantly, new technologies are already changing the international division of labour and influencing the pattern of world trade. As we mentioned in the previous chapter, global production strategies made possible by the use of modern technologies are enabling transnational corporations to reap the benefits from changes in international competitiveness through locating their production facilities in the lowest cost areas and sub-contracting particular processes to the lowest-cost suppliers. Many of the newly-industrialising and some other middle-income countries are benefiting economically and technologically from such arrangements, but many other developing countries are being disadvantaged through the resultant trade and investment diversion. Some developed countries have also suffered, as the ongoing process of developing new technologies is continuing to alter the balance of competitive advantage between countries. All aspects of industrial production, from raw-material sourcing to marketing and transport, as well as labour relations, are being affected. Increased automation in manufacturing, using computer-controlled processes including robotics, means that relative wage rates are becoming less important even in traditionally labour-intensive industries like garment making, and have enabled developed countries to become competitive again in some sectors. And the pace of this process is accelerating. Some developing countries have however been able to maintain their competitive advantage by adopting new technologies; but since these are usually costly as well as labour-saving, they have been mainly restricted to export industries, even in the newly industrialising countries.

8.16 As noted earlier, new technologies are also increasing the tradeability of services and blurring the distinction between them and goods. Traditionally the nature of most services meant that with the exception of shipping and airlines, only a small proportion entered world trade. But new information technologies have facilitated

the increasing export of financial, banking, insurance, data processing and related professional services. They have also facilitated travel and have therefore helped to promote tourism. Developed countries see tremendous potential for exporting knowledge-based services, and in the GATT Uruguay Round and other fora have been trying to persuade developing countries to reduce their controls on the import of such services. Technology developments are likely to have mixed results as far as developing countries' services are concerned. These countries' economies may benefit from increased tourist receipts and from greater investment; but in some cases this may only be at the cost of environmental deterioration, increased external dependence, and a lack of control over services.

8.17 As food and raw material producers, developing countries' interests can also be profoundly affected by new technologies. For example, biotechnology can, on the one hand, multiply agricultural yields and varieties and enable crops to be produced on marginal lands, thereby assisting these countries to feed their people better, increase agricultural exports and reduce food imports. But on the other hand, it can increase the yields of temperate products and enhance their competitiveness; it can enable tropical crops to be grown in temperate climates; and it can destroy demand for conventional commodities by providing synthetic or other substitutes. This last characteristic is true of other new technologies, for example the substitution of fibre optics for copper. New technologies can also reduce raw material requirements through increasing efficiency in utilisation, miniaturisation and reduced need for inventories. This process of substitution has been at work for a long time but the new trends in technology may well have caused it to accelerate.

Technology Policy

8.18 The widening gap in living standards between developed countries and most developing countries is attributable in part to the widening gap between them in the efficient application of research and development (R&D) to production processes. This, in turn, depends to a considerable extent on linkages between applied R&D and production. It is also evident in the different proportions of the labour forces of developed and developing countries who possess scientific and technical skills, and in the comparative expenditures on R&D in the two categories of country. In the 1980s the OECD countries devoted about two and a half per cent of their GNP to R&D, while the corresponding expenditure by developing countries was less than one per cent of their much smaller GNP. Total R&D expenditure in 1988 was estimated at around \$350 billion in the developed countries, whereas in the developing countries it was only around \$20 billion, spread over a much larger population.

8.19 The pace and complexity of technological change confront developing countries with daunting problems. If they do not keep abreast, they risk becoming increasingly uncompetitive. In many cases they have the capacity to exploit new technologies. But if they are to do so, clear and positive policies are needed on scientific and technical training, as well as on technology monitoring and evaluation, adaptation and development, and utilisation and diffusion. In view of their circumstances, developing countries should pay particular attention to policies for technology transfer, something we consider in the next section. The need for clear and positive policies applies also, of course, to industrial countries, as does the need for policies on technology transfer in view of the complexity and widespread application of modern technology development.

8.20 A policy to enhance human resource development is crucial to all elements of technology. Scientific and technical knowledge and awareness of technology developments internationally are needed to guide the formulation of technology policy (including technology transfer), and to make effective use of technology by being able to identify, evaluate and assimilate those which are suited to domestic circumstances and to adapt those which are not. There is also need to undertake overall technology assessment related to economic and social need. All this must rest on an infrastructure of human resource development, especially education in the application of physical sciences.

8.21 We have considered human resource development in Chapter 5 but here we should emphasise the importance of developing countries increasing the proportion of budgetary expenditure devoted to education and, within it, raising the amount spent on scientific and technical training. This need extends from primary to tertiary level, as is evident from the glaring differences between developed and developing countries. In the developed countries the ratio between technology-related and white collar types of tertiary-level course enrolments is of the order of 50:50; in the developing countries it is of the order of 10:90. And because of the much lower enrolment rates at tertiary level in developing countries (see Annex Table 5.5 on p.171), the real differential between the number of technology students in developed and developing countries is far more than the 5:1 implied by these figures; it is probably in excess of 20:1. One of the main reasons is the much higher cost of technology-related courses. In some developing countries, the lack of demand for technologically and scientifically trained graduates also contributes both to the 'brain drain' (see para.5.41) and to low enrolment, creating a vicious circle which obstructs a transition to higher technology development. One of the main tasks for developing countries is to reorient their educational and training programmes more towards science and technology. Similarly, it is necessary for all countries to

encourage computer use and computer literacy because of the pervasive importance of computer technology, especially in manufacturing and services. Where import restraints on hardware and software constrain wider computer use, we believe they should be reviewed and if possible removed.

8.22 In shaping their technology policies, developing countries need to build a capacity to monitor and evaluate technological developments and to forecast, if only in general terms, the likely course of events. The aim here will be to distinguish those technological advances useful to a country in its particular circumstances from among the bewildering mass of technological developments.

8.23 There is no doubt that indigenous development of technology is important for developing countries, especially in fields such as agriculture where specific production circumstances require effective local and regional R&D. For many developing countries, however, it is not crucial in the initial stages of most other sectors, where greater reliance can be placed on technology transfer and adaptation.

8.24 Developing countries need policies to encourage technology development, adaptation and absorption. In addition to measures providing for or promoting appropriate scientific and technical education and training, this requires support for indigenous research and development, programmes to diffuse technological knowledge and its application, and the encouragement of innovation and competition.

8.25 We recognise that it is often very difficult for developing countries to cope on their own with technological change. Small developing countries will find particular problems in attaining the minimum thresholds required for R&D, training of high-level personnel and creation of technological capacity generally, from within their own resources. This is an area clearly calling for regional cooperation. But bilateral and multilateral cooperation can also be of help. The continuing weakness of local R&D institutions and other indigenous efforts in most developing countries emphasises the importance of joint ventures with relevant R&D institutions in developed countries. These possess many scientists and technologists who, with some facilitating assistance, could be harnessed to help develop and adapt technology in developing countries.

Technology Transfer

8.26 No country, even the most economically advanced, can expect to develop itself all the technology that it wishes to use; developing countries, in particular, need to import technology to upgrade their

domestic activities and compete internationally. To do this effectively requires the capacity to identify and evaluate appropriate foreign technologies. These can be acquired in different ways (see Box 8.1 below). Most of them are owned by private interests, particularly the transnational corporations. Many developing countries will be at a disadvantage in negotiating to acquire these corporations' technologies. They need to exercise great care and on occasion seek assistance to ensure

Box 8.1

Technology Transfer

The main means of technology transfer are through direct foreign investment (equity participation, joint ventures, subsidiaries of transnational corporations); direct transfers of technology (patenting, licensing agreements, technical consultancies, management service contracts, on- and off-the job training); imports of capital goods (often in association with other transfer elements such as information on technical specifications, training, consultancy); turnkey projects (sometimes involving an entire enterprise); reverse engineering (i.e. unpackaging technologies); and non-negotiated transfer, such as screening of foreign journals, direct observation by scientists and technicians at universities and R & D institutions abroad, etc.

These methods of transfer involve different costs and benefits to the receiving country in terms of price, control, and ability to absorb or adapt the technology concerned, or develop totally new processes or products. Any one method may be appropriate in particular circumstances, but the aim of developing countries is to acquire technology at a fair price, on reasonable terms and conditions, and with maximum effectiveness in developing their indigenous assimilative and innovative capacities.

In order to evolve a coordinated technology development strategy, developing countries need to strengthen their human resource capabilities (through technical education, vocational training, etc); institutional systems (R & D institutes, technology development centres, consultancies, diffusion and extension services); organisation arrangements (data-banks, patenting, rule- and standard-setting); and administrative capabilities (technology forecasting and assessment, technology and related industrial and trade policy-making, negotiating capacity etc.).

that the technologies are transferred to them on equitable terms. They need also to secure appropriate training for local staff, a right to sell the resultant products or services freely abroad as well as at home, and rights to adapt and diffuse the technology in question. As the experience of South Korea has proved, an ability to unbundle packages, acquiring what is needed and rejecting what is not, is of particular relevance in this respect.

8.27 From a policy standpoint, technology transfer is a complex issue. There is sometimes a need to reconcile the protection of specific areas of economic activity (perhaps for reasons of security or other public policy) by restricting imports, with the maintenance of a non-discriminatory and liberal trade regime (for reasons of general development). Such matters can probably be resolved only on a country-specific basis. Whereas selective protection was a component in the industrial successes of some countries such as Japan and Korea, in others policies restricting the use of imported technology have had mixed results: considerable success sometimes in terms of fostering technological development domestically, but failure in terms of promoting overall economic growth due to the uncompetitiveness of the technologies fostered in this way. In general, liberal import policies appear to have been more effective in promoting technological progress and economic growth when assessed together.

8.28 The control of technology transfers remains a crucial policy issue in many developing countries, as the evolution of biotechnology illustrates. The products and processes of the 'gene revolution' are now largely in the hands of transnational corporations and specialist companies in the developed countries. Their control has made access more costly and in other ways more difficult for developing countries in two respects. One is the extension of intellectual property rights to plant and animal products and biotechnology processes. The other is the increasing proportion of academic research which is commissioned by, and contracted to, industry; previously widely disseminated, this is now either shrouded in secrecy to protect commercial interests or available only at a high price.

8.29 This underlines the need for greater collaboration and networking between universities or public sector research institutes in pure and applied science. Biotechnology is a particular case in point. Greater support is also needed for publicly-funded collaborative efforts in advanced technology. In this connection we welcome UNIDO initiatives in establishing international centres of excellence—on Biotechnology and Genetic Engineering, and on Science and High Technology—and urge that they be strongly supported.

8.30 Access to technologies could be made more difficult by other developments in the international sphere. In the fora concerned with

structuring the international commercial, legal and scientific environment affecting the transfer and use of technology, the developed countries have been pressing for extended and tighter control of industrial and intellectual property rights. As we noted in Chapter 7, Governments such as the United States have (under Section 'Super 301' of its 1988 Omnibus Trade and Competitiveness Act) threatened bilateral retaliation against countries not adhering strictly to international agreements on such rights. The treatment of these rights remains at issue in the GATT Uruguay Round of multilateral trade negotiations (as pointed out in Chapter 7). They are also under revision in WIPO (Paris Conventions on Patents and Copyrights, etc) and UNESCO (copyright conventions etc.).

8.31 Also of concern to developing countries is the possibility of collusive action: by transnational corporations to restrict access to technologies, and by industry associations to control trade in 'technology products' (such as arrangements between US and Japanese companies on trade in integrated circuits). We acknowledge that this is a problem, and that governments do have a role in ensuring fair competition practices, but we believe the crucial need for them is actively to encourage and facilitate transfers of technology, for example by joint ventures. In other words, to promote an approach that is more business-like than legalistic.

8.32 On the other hand, while recognising that technology development frequently requires massive initial investments, that those who make these investments will want to sell or license the resultant technology profitably, and that intellectual property rights must therefore be adequately protected through internationally agreed rules, we feel that the technologies themselves should be widely available on equitable terms. If the outcome of the GATT negotiations is less than satisfactory to the developing countries in this respect, we consider that there will be need to devise new mechanisms to foster the transfer of technology to them, including subsidising the payment of fees for industrial and intellectual property rights. Official development assistance may have a role to play here. For example, there will be instances, perhaps particularly in the environmental field, where a coincidence of interests between developed and developing countries will justify special arrangements to provide technologies on a non-commercial basis through such assistance. We explore this point further in the next Chapter.