Part II
Chapter 1

The Impact of New Technologies

1.1 In this Chapter we attempt to assess the economic and social impact of new technologies. We focus in some detail on economic growth, employment and international trade, and give particular consideration to the impact on developing countries.

1.2 We have concentrated on the four key emerging technologies of microelectronics, biotechnology, new materials technologies and renewable energy technologies. But we have also been conscious of the wider role of technology in the development process, including the impact of more established technologies and of other emerging technologies not discussed here. It is obvious, too, that the impact of new technologies will be strongly influenced by the economic context. Both the current rate of diffusion of new technologies and the scale of their impact reflect the fact that the world has been through a prolonged period of economic recession, and that innovation and structural change have therefore been at comparatively low levels. In particular, the overall situation of very many developing countries has deteriorated. The difficulties facing developing countries, especially the shortage of foreign exchange, have highlighted problems which, in a more dynamic economic situation, these countries would have been able to accommodate. Those developing countries which in the past have been largely dependent on imported technologies in the form of equipment, can no longer afford to maintain or update their technology. Those which have not been able to develop indigenous technological dynamism, and therefore lack the skills to facilitate structural change, have not only been adversely affected in the short term but face additional difficulties in extracting the maximum benefits from the new technologies.

1.3 We have focused on the four key emerging technologies because of their potential for radically altering economic and social conditions.

Each is at a different stage of development, innovation and diffusion but all are operational to some degree, so some evaluation of their impact is possible. An important development is the tendency for new technologies to reinforce one another and so make possible new products, processes and systems. These 'synergetic' effects, already visible in microbiology and electronics, or in optical technology and new materials, are expected to become increasingly important.[1]

1.4 In order to put the discussion into context, we first summarise salient features of the four main emerging technologies (giving more details in Volume II, Appendices 1–6) and then briefly mention their relationship with mature, modern, technologies.

I. DEVELOPMENT AND APPLICATION OF NEW TECHNOLOGIES

Microelectronics

1.5 Although the term 'microelectronics technology' has often been equated with the semiconductor industry, it can be applied more widely to an interlinked set of electronics industries. These can be divided into four main groups: the components industry, including particularly semiconductors/integrated circuits but also involving a wide range of other passive components; the information processing industry, based on the development of computer and related software technologies; information transferring industries, especially in the field of telecommunications; and electronic applications in other sectors, such as factory automation, instrumentation and medicine.

1.6 The evolution of the electronics sector has been marked by exceedingly rapid product and process innovation since the introduction of the transistor and the electronic computer less than 40 years ago, based on advances in solid state physics. Seminal events in the evolution of microelectronics components technology include the discovery in 1947 of the germanium point contact transistor, which replaced vacuum tubes; the invention in 1961 of the integrated circuit; and the development in 1971 of the microprocessor, which made it possible to incorporate all the elements of a computer on a single chip. Since 1971, the dominant technical trend in semiconductors has been the rapid and continuous reduction in circuit size and the corresponding increase in chip density. This has led to an enormous rise in the amount of information that can be handled and an equally impressive reduction in the time required to do it. In consequence, since 1971, there has been an average annual reduction of around 35 per cent in unit cost of random access memories (RAMs). This trend has, in turn, stimulated rising demand for microprocessors.

1.7 The major innovating agents have been private firms, initially in the electricity and telecommunications industries, but later largely within the semiconductor industry itself. These enterprises have often been supported by government R & D and procurement policies, especially for defence and space projects in the United States.[2]

1.8 An understanding of the key characteristics of microelectronics gives some indication of its importance. Since microelectronics relies on digital logic, it is essentially an information processing technology. Microelectronic devices are applicable in any situation in which rapid processing of information, in its broadest sense, is required. Most importantly, the use of digital devices can create a 'universal language' for information processing and transmission. They can replace a wide range of electrical, mechanical and other devices or be incorporated into products to improve the reliability and flexibility of performance. Moreover, the devices are programmable and therefore a single chip design can be adapted to a myriad array of applications. This, together with increasing chip density, makes microelectronic devices much more cost-effective than other information processing systems. These characteristics allow the 'real time' or simultaneous handling of complex information which has proved crucial in the development of highly sophisticated process-control systems and automation technologies such as flexible manufacturing systems (FMS) and computer-aided manufacturing (CAM).

1.9 A final feature of the application of microelectronics is the way in which it occurs in a series of distinct phases. New technology is normally introduced at the level of the individual machine or production function. At the next stage it is used in 'linking' activities in related fields, and this is the phase which most of the current applications have reached. The third stage, whose impacts lie mostly in the future, will see the spread of these linkages to integrate design, manufacturing, management and control activities. While FMS may be said to represent the boundary of 'linking' within the manufacturing process (i.e. the second stage), the third stage would see developments based on concepts such as 'just-in-time' systems. This phased application is reflected in the diverse levels of technology diffusion in different countries and industry sectors.

1.10 The forces of these new capabilities is magnified yet again by the synergetic gains of integrating different technologies. For example, computer-aided design (CAD), which was developed in the US defence and aerospace industries during the 1950s and 1960s, subsequently spread to the electronics sector where it quickly became an essential tool in the design of integrated circuits and computers. And as manufacturers of semiconductors spread into the production of computers and other consumer electronics, the convergence of operations between sectors led to strong mutual influences; for example, new designs for integrated circuits depend on computer languages, while modern telecommunication systems are essentially dedicated to computers. This convergence has already blurred the distinction between the main industry groups so that much of the debate now focuses on 'information technology' rather than sectoral issues.

1.11 This convergent technology has two main areas of application: in information processing and transmission, which are of particular relevance to the services sector and to organisational and management activities in other sectors; and in automatic control and monitoring functions, which relate largely to manufacturing but also to primary industry (notably mining and agriculture).

1.12 As regards the first of these applications, the ability of microelectronics technologies to process, store and retrieve information rapidly and cheaply in miniaturised form is leading to many uses. Microelectronic devices have been incorporated into word processors, electronic typewriters, facsimile machines, calculators, cash registers, computer terminals and peripherals (including point-of-sales terminals in the distributive trades and cash dispensing devices in banking), as well as into telecommunications equipment. Telecommunications are being simultaneously influenced by advances in microelectronics and by a range of new and distinct telecommunications technologies which include fibre-optics, microwave radio transmissions and satellite systems. Further, multi-purpose, and often internationally integrated, digital networks are becoming established incorporating developments in improved text transmission systems such as high-speed facsimile machines, teletext services, view-data terminals, electronic switchboards and other elements. Improved telecommunications will have wider influences; for example, the use of cable and satellite television. The 'systems' gains which may be achieved through linking appropriate products into networks permit vast improvements in and new combinations of services provided by offices, banking, insurance, telecommunications and distributive trades.

1.13. In processing and manufacturing, microelectronics can help to control and monitor such items as the movement of materials, components and products; the level of process variables such as temperature, pressure and humidity; the shaping, cutting, mixing and moulding of materials; the assembly of components; the quality of products as determined by inspection, testing and analysis; and the organisation of manufacturing, including design, stock-keeping, dispatch, machine maintenance, invoicing and the allocation of tasks. Thus it can be used in continuous process industries (such as chemicals, glass, ceramics and steel); for smaller-scale plant by providing greater product flexibility in batch production; and, in mass production, to integrate automated units and achieve greater efficiencies through closer links between design, production, marketing and stock-keeping.

1.14 In agriculture, microelectronic devices can be used in many operations: crop spraying, sorting, cleaning and packing; irrigation; controlling animal feed rations; regulating glasshouse temperatures; and automating tractors and other farm equipment. In mining, they can be used for materials handling and washing and in remote-control face-working; they can improve smoke detection and other aspects of environmental control; and, linked to satellite communication, they can help in mineral exploration. In relation to public utilities like energy, road, rail and air transport, these devices can be used to monitor flows, as well as carry out many administrative functions such as labour scheduling, billing and accounting and, in the case of transport, bookings.

1.15 Microelectronic devices can be incorporated into many products requiring some form of control or monitoring mechanism or data processing function. These devices have already been incorporated into domestic appliances such as washing machines, ovens, vacuum cleaners, telephone answering and call analysis systems, door locks and bells; into entertainment products such as television sets, high-fidelity equipment, video games and recorders; and into automobiles to control ignition, exhaust emission, fuel metering and voltage regulators.

1.16 Finally, microelectronics has a growing variety of applications in enhancing the capabilities of other technologies. It has combined well with biotechnology: for example, computers can analyse and store data on molecular structures and assist in disease diagnosis and health monitoring. It can also combine with traditional technologies: relevant applications include food storage and moisture control; sprinkler control for irrigation; computer prediction of optimum planting dates; sorting and grading of agricultural produce; and quality control for small manufacturers. Microcomputers have also been proposed for use in land-use analysis, while the practical value of electronic devices in controlling flows of renewable energy like biogas and hydropower has been illustrated by UNIDO and ILO.

Biotechnology

1.17 On a broad definition,[3] biotechnology has a long history. What might be called 'traditional' biotechnology has produced many advances: in the use of fermentation organisms; in plant and animal breeding, such as artificial insemination of cattle and artificial propagation of fish; in antibiotics, serum and vaccines; pasteurisation and sterilisation of foods; innoculation with rhizobium cultures to enhance legume yields; high-yielding seed varieties; the biological control of crop pests. It is, however, necessary to distinguish a new, 'high-tech', biotechnology based on practical applications of the most recent advances in chemistry, biology and genetics. These include genetic and cellular manipulation (including 'cloning'); enzyme production and reaction; fermentation related to the large-scale growth of living organisms and the removal or extraction of resultant substances (for example microbes for producing fuel or feedstock). The main focus of our Report is on 'new' biotechnology but it is expected that at least in the medium term, 'traditional' biotechnology will continue to be of greater importance, particularly to the economies of developing countries. For example, the introduction of high-yielding plant varieties in the 1960s, which ushered in the 'green revolution' in many parts of the Third World, especially in South and South East Asia, was based on 'traditional' biotechnology combined with better management practices.

1.18 Modern biotechnology owes much to Pasteur's work on fermentation in 1910, which led to the large-scale production of basic chemicals (for example acetone, butanol and ethanol) and, during the Second World War, to penicillin followed by other antibiotics and steroids, enzymes and certain vitamins. Knowledge of genetics has expanded since Mendel's work, and advances over the past thirty years have been particularly crucial. Since the discovery of the chemical structure of DNA[4] by Watson and Crick in 1953, scientists have developed genetic engineering techniques, and it is with these techniques that 'new' biotechnology has largely become associated. In 1973 developments in recombinant DNA technology enabled scientists to engineer or introduce genes from one organism to another to give the recipient its desired characteristics. This allowed, for instance, the genes for producing human growth hormones, insulin, or anti-viral interferon to be inserted into fast-growing bacteria or yeast and fungi. Similar advances in cell fusion occurred after 1975 with the production of hybrid cells called hybridomas. These were able to multiply rapidly in culture to give rise to identical cells (clones) which produce monoclonal antibodies (MCAs). So far the main use of MCAs has been to detect the presence of disease and thereby facilitate earlier diagnosis, but in future they may also be used to detect pollutants in water and air, to transport anti-cancer medications to specific cancer sites, and, in industry, to separate valuable substances from large quantities of reaction mixture in order to purify them.

1.19 Biotechnology R & D has proved to be a high-risk activity, and government support has been vital, particularly in the early stages. In the developed countries this has taken the form of full or partial funding of some basic research by universities and specialised centres, as well as by industrial enterprises, for whom governments have also on occasions made available resources or provided incentives for the commercialisation of R & D. But small-scale firms engaged in biotechnology R & D and consultancy work are largely financed by venture capital. Large-scale transnational enterprises, primarily engaged in pharmaceuticals, chemicals, petroleum and beverages, have developed strong links with universities and venture capital firms, and have established their own biotechnology R & D, manufacturing and marketing units. The US industry has been particularly dynamic, with over 100 biotechnology companies established between 1976 and 1983 and twice the sales of West European and Japanese firms combined.

1.20 Biotechnology applications are potentially wide but one of the most important contributions is opening up in food and agriculture. Applications in food include traditional fermentation technology, like brewing and bread-making, and new fermentation products, such as protein enhanced foods and polysaccharides, as well as products resulting from enzyme engineering (including amino acids and sugars from starch). Through genetic engineering it is proving possible to enhance the nutritional or other values of plants by increasing their product size and ratio of edible matter to waste, extending their growing season or geographical range, reducing their growth cycle to permit more harvests per year, increasing their density, and strengthening their resistance to disease and climatic variations. In addition, since the two major increases in petroleum prices during the 1970s, there has been a greater interest in nitrogen-fixing organisms to raise soil fertility and lessen the need for chemical fertilizers; genetic engineering has the potential to develop crops which produce their own nitrogen. Genetic engineering will also make considerable contributions to animal husbandry: through the development of vaccines and antibiotics to control disease; the supply of growth promoters or hormones; and the improvement of genetic characteristics to control the sex of offspring and enhance the conversion of animal feed to animal protein. Biotechnology will also help to upgrade the quality of livestock through developments in embryo transplant technology. By this means live frozen embryos are shipped, rather than selected animals. Such embryos can be implanted into a surrogate mother at the destination but will retain their own selected genetic characteristics.

1.21 The largest application, so far, of new biotechnology has been in healthcare. The high costs of producing low-volume, high value-added biotechnology products have not been a major constraint in the health sector of developed countries and are beginning to produce 'spin-off' benefits in high volume sectors. In developing countries, biotechnology for therapeutic uses in medical and veterinary care is likely to become more important in time. Genetic engineering also offers the opportunity for large-scale manufacture of many drugs and vaccines of relevance to developing countries and at modest cost.

1.22 In industry, biotechnology is applicable to a number of processes. Most importantly, it is expected to revolutionise the manufacture of chemicals, as micro-organisms can accomplish in one step, processes that under existing technologies are multi-stage. Moreover, biological processes do not require the high temperatures and pressures of conventional processes and hence are generally less energy- and capital-intensive. Chemical products which can be manufactured by biotechnology processes include plastics and resins, perfumes, synthetic rubber, ethanol and methanol, and pesticides and herbicides.

1.23 Another major area of application of biotechnology is in energy production. We deal with this more fully below but it is enough to point out here that since a large number of people in developing countries rely on biomass for domestic fuel, biotechnology can contribute to increasing energy supplies (for example through cloning plants from prolific and fast-growing varieties of tree species) and, where necessary, improving the conversion of biomass into fuel. Improved petroleum recovery techniques using micro-organisms or microbial products, together with new methods of converting waste material into energy and energy-related products, can further contribute to energy supplies. Biotechnology is also applicable to other types of mining (such as the use of micro-organisms in leaching metals from low-grade ores).

1.24 In the longer term, biotechnology is likely to make an impact on pollution control and waste recycling (including water purification), thereby contributing to protection of the environment and conservation of natural resources. There are a wide range of potential waste substrates from agriculture, forestry, industry and households which can be used for fuels, chemicals, buildings blocks, fertilizers and animal feed. The long-term effects of biotechnology are likely to be considerable on virtually every facet of the economy, in both developed and developing countries.

New materials technologies

1.25 In recent years, considerable R & D has taken place into new materials. There is nothing intrinsically 'new' about new industrial materials; metallurgy and petrochemicals are well established sources. But the combination of special needs (for example space and defence) and concern over the depletion of non-renewable raw materials has created a new wave of product and process technologies. The resulting developments have created materials which are both organic (such as plastics and rubber) and inorganic (such as ceramics, new cements, metals and alloys), and include composites (for example combinations of new fibres—such as carbon, boron and polyamide—with polymers, metals, ceramics and cements). In all cases they possess improved characteristics such as purity, durability or strength. New process technologies include methods of forming close to final shape, of joining, and of providing greater durability. While many of these technologies are still in the early stages of development, and some of them might not be fully commercialised for over a decade, others are likely to become very important even in the shorter term.

1.26 Already some trends are becoming apparent. Among them is the swing away from petrochemical feedstocks (traditionally used in many plastics) and metals towards polymers and ceramics based on common elements (notably oxygen, silicon, calcium). These trends imply that the resources needed for at least some materials of major future importance will be essentially available to all countries, rich or poor, whether petroleum endowed or not. It also seems likely that comparable developments in processing technology will make it possible to produce many of them in developing countries using relatively low-cost techniques appropriate to local conditions, with all the ensuing advantages this would entail. Some aspects of the technological development and application of certain new materials and processes are briefly summarised in the following two paragraphs. Those chosen are engineering ceramics, high-strength low-alloy (HSLA) steels, powder metallurgy, polymers, composites and joining technologies.

1.27 Technology to produce engineering ceramics is costly and still mainly at the R & D stage, but the number of elements which can be used is widening, which should reduce costs. That to produce the steels for which ceramics are likely to become increasing competitors is in general much more mature, though developments are still occurring, especially for HSLA steels and in powder metallurgy. Among other important new materials, technological advances continue to be important in extending the range of fillers and of feedstocks (other than petroleum) which can be used to produce polymers (plastics), and the feedstock may eventually include biomass. The number of composite materials is increasing and R & D continues to enhance their technical characteristics, especially those composed of fibre-reinforced polymer matrices and metal matrices. Among a series of advances in processing technologies, some of the most significant relate to the joining of different materials, for example through laser welding, diffusion bonding and layer coating. Together with adhesive bonding, these are likely to play an increasing role in manufacturing, especially where automated techniques such as robots are used.

1.28 These new materials have many applications. Engineering ceramics, for example, possess properties specially useful in the future manufacture of diesel and gas turbine engines, cutting tools and certain types of process plant; but it is also likely that they will find use in medicine and dentistry. HSLA steels are being increasingly used in applications which require low weight combined with high strength (such as road and rail vehicles, bridges and cranes). The high strength to weight and modulus to weight ratios of the new composite materials make them ideal for a wide range of applications in the engineering and construction industries, especially where direct moulding into final shape is required. Materials such as composites and polymers, together with processes such as advanced types of bonding, are also finding new uses in the motor vehicle industry.

Renewable energy technologies

1.29 We have hitherto dealt with major technologies whose direct uses extend over many sectors. The energy sector repays separate attention since it has seen a variety of major technological innovations, particularly after the stimulus provided by higher petroleum prices. These innovations include techniques to increase efficiency in converting primary energy into secondary energy (for example thermal electricity—where in some processes over half the primary energy is normally lost as waste heat); in specific end-uses of energy (such as heat pumps and fluidised-bed combustion); and in overall consumption of energy (mainly through better organisation of the thermo-dynamic balance in industries).

1.30 Another major development is the greatly increased interest in renewable sources of energy, notably those of special interest to developing countries.[5] Such sources fall into six broad categories: bioenergy, in its traditional solid form as biomass (fuelwood, wastes etc.) or converted into liquids (ethanol and methanol) or gas (biogas/methane and producer gas); solar power; wind power; hydroelectric power, including mini-hydro; geothermal energy; and ocean energy (waves, tidal and ocean thermal gradient).

1.31 Few renewable energy technologies have yet matured to their full potential. Some which have been commercialised, including biomass conversion, wind turbines and solar photovoltaic cells and arrays, are undergoing rapid development, with increasing technical effectiveness and declining costs. Others await full economic assessment although their technical viability has been demonstrated (as in ocean energy); still others are not expected to become economic over the next 20–30 years (for example the photobiological production of hydrogen). Most of them are particularly suitable for small-scale users, especially in the rural areas of developing countries. Some are especially appropriate for use in the household (biomass for cooking, biogas for lighting and cooking, low-grade solar thermal energy for space and water heating); others in agriculture (biogas, micro-hydro, small windmills); or transport (ethanol in substitution for conventional motor spirit); or electricity generation (large-scale hydro and, to a limited extent in exceptional situations, biomass, windpower (aerogenerators), ocean energy (tidal plants), solar energy (both thermal and photovoltaic) and geothermal energy). Few are able to provide high grade heat for industrial processes, although geothermal energy can be used for this purpose. They are, however, much more appropriate in supplying energy in special situations, for example from photovoltaic systems in remote locations or hostile environments for, say, communication or navigation purposes. But we should not risk giving any impression that these technologies will provide unlimited supplies of energy in the next few decades. Though they are likely to increase in importance for particular countries, regions or purposes, and have a considerable impact on ways of life, their contribution to global energy supplies will remain small in the foreseeable future unless there are exceptional advances in technology or breakdowns in supplies of fossil fuels.

1.32 One final point we should emphasise in connection with renewable energy technologies concerns the importance of integrated energy systems, making use of several different energy sources in combination. These can contribute to reliability in supplying energy and can be more cost effective than single sources. New technologies to optimise energy flows are being incorporated into these systems and, here, a combination of new energy technologies and microelectronics-based control systems is of growing importance.

Other new technologies

1.33 The concept of 'new technologies' would be misleadingly narrow if it referred only to the 'emerging' technologies discussed above. It must also relate to incremental improvements in existing processes and products and the use of technologies which are new in a particular context even if technically mature and commonly used elsewhere.

1.34 Several basic industries commonly regarded as having mature technologies have recently experienced significant changes. For example, steel has seen a virtual phasing out of converters and open hearth furnaces which have been supplanted by basic oxygen and electric arc furnaces, with consequent increases in efficiency; nor have advances in technology been restricted to the smelting stage, as the development of continuous casting has shown. Similarly in textiles, another industry important for many developing countries in the early stages of industrialisation, technical developments have abounded in the last twenty years or so, including the advent of open-ended spinning machines and shuttleless looms.

1.35 In agriculture, too, technologies normally thought of as 'mature' are continuing to be adapted, upgraded or introduced into particular locations. They are having an impact both on production and processing and on utilisation, with especially marked effects on some developing countries. To take sugar as one example, new or improved techniques are raising extraction rates and creating new uses, such as conversion into alcohol and transformation of cane waste into paper board and building materials. Similar advances are occurring in other commodities.

1.36 As far as developing countries are concerned, most new production processes have been introduced by means of technology transfer in various forms: direct foreign investment; embodied in imports of capital goods; or disembodied in the know-how incorporated into patents, licences or technical and professional services. This transfer has then been followed by a period in which these imported technologies could be adapted to suit local requirements. The time taken for adaptation has permitted a period of cumulative skill creation within the developing countries concerned which, together with the development of associated infrastructures, has given them an opportunity to develop their own technologies. This process has, however, largely been confined to the NICs—South Korea being perhaps the best example. In these countries the accumulation of technological skills, together with an export orientation, has been significant in stimulating a move up the technological ladder and in some cases into emerging technologies. Many other developing countries have, however, not yet entered or been able to enter this process. Yet others are concerned more with changing the character of technology in a more fundamental way: for example, to create 'appropriate' technologies for basic needs.

II. ECONOMIC AND SOCIAL EFFECTS OF NEW TECHNOLOGIES

Economic growth

1.37 The most important impact of new technology is on economic growth and the resulting improvements in living standards. The interrelationship between the application of technology, increase in productivity and growth of an economy has long been recognised, but it was not until the 1950s that more precise attempts were made to estimate the contribution of technological change to the performance of an economy. There are still many practical problems in measuring these effects and such estimates are therefore normally treated as indicating orders of magnitude rather than as presenting precise measurements. Nevertheless, the evidence clearly suggests that technology has been highly significant, and in some cases the major factor in economic growth.[6] It indicates that in most developed countries the economic and social effects of technological change began to accelerate after World War II, and that this phenomenon lasted at least until the 1974–75 recession. It was especially marked in the United States and some of the larger countries of Western Europe during the 1950s, and in Japan and some of the smaller West European countries during the 1960s, when the latter began to catch up with the more technologically advanced countries. More recently, some studies suggest that new technologies have been the cause of much of the recent recovery in output, especially in Western Europe, although this has not been accompanied by a commensurate revival in employment.[7] In the developing countries the effects of technological change are less well documented but they may well have been more marked during the 1970s than the previous two decades.

1.38 While it is generally agreed that technological innovation has been a major factor in economic growth, there are arguments about the mechanisms involved. One plausible and well established set of arguments emphasises that innovations tend to be concentrated in key sectors and at certain periods of time. The diffusion of innovations then follows a cyclical pattern which starts slowly but accelerates as an increasing number of enterprises perceive the profitable investment opportunities associated with the new technology, and 'swarm' to take advantage of them by developing new products and processes. This 'swarming' has powerful multiplier effects which impinge on the whole economy and lead to long upward movements in investment, output and employment. But, over time, the 'swarming' process slows as increased competition erodes profit margins and the emphasis shifts towards rationalisation and cost-reducing innovations—which, because of standardisation and scale economies, have less potential to generate employment. As a result, growth decelerates and stops, and ultimately the economy enters into decline—until a new wave of innovation restarts the growth process.[8] Looked at in this way, history shows successive bursts of economic expansion and decline following the diffusion of major innovations such as the steam engine, the steel furnace and the petrol engine. The effects in currently emerging technologies could be the same.

1.39 But if the relationship between technological change and economic growth at a macro level is difficult to measure precisely and somewhat controversial to explain, the effects on particular sectors of the economy are much more tangible. The main direct effects of *microelectronics* technologies are felt within the electronics sector itself. In the United Kingdom, for example, the introduction of new technologies was instrumental in raising the growth of labour productivity in the sector from an annual average 4.7 per cent during 1954–74 to 6.8 per cent during 1974–81, at a time of much slower growth in the economy. Within the sector, labour productivity rose especially quickly in the production of computers and (since the mid-1970s) electronic capital goods. Capital productivity has also risen, especially in the manufacture of computers. If the limited evidence available for this sector were to be true of others, then there would be less concern about growth leading to labour displacement.

1.40 Microelectronics technologies have also had widespread effects on productivity in manufacturing industry outside the electronics sector, especially in engineering. Case studies have shown that the replacement of conventional machine tools by those which are computer numerically controlled (CNC tools) can raise labour productivity by a factor of two or three, and there are comparable results from the use of computer-aided design (CAD) equipment. Linking CAD and CNC tools leads to even higher increases in productivity than figures for their separate use would imply.

1.41 The versatility of CNC equipment, which enables a single machine to do the tasks previously carried out by several, has also led to savings in fixed capital investment. Capital saving has also been facilitated by shorter changeover times and greater use of 24-hour production shifts incorporating robot tools and machines. Costs of working capital have been reduced, and the use of CNC, CAD and flexible manufacturing systems (FMS) has allowed savings in inventories. There have been economies in the use of raw materials as a result of better product quality and production design; to take one example, in the metal-working industry the creation of scrap has been halved in some cases.

1.42 One sector traditionally associated with the early stages of industrialisation, and thus of particular importance to developing countries, is textiles and clothing. Microelectronics-based technologies have begun to affect all textile processes, particularly design (CAD), and in the control systems for fibre preparation, weaving, knitting and finishing. They have become especially important in the automation of cloth dyeing and other finishing processes. As a result primarily of introducing these technologies, developed country textile firms have reduced their price disadvantages compared with leading Asian producers from 30 per cent to almost 10 per cent since the mid-1970s. In clothing, computers have been used for designing and cutting garments, in certain sewing operations, and in pressing. Although the use of equipment incorporating microelectronics has been limited in sewing to specific individual tasks, in those instances labour productivity has increased by an average of 45 per cent. Taking into account the relatively low rates of diffusion, in the short term, it is expected that these changes will lead to an overall increase in labour productivity in the clothing industry of 5 to 7 per cent annually compared to 3 per cent in the 1970s. In the longer term the development of FMS for clothing may lead to even greater increases in productivity, with as much as a 50 per cent reduction in production costs being sought by the Japanese.[9] Such developments, apart from affecting productivity, have considerable implications for international trade.[10]

1.43 The development of microelectronics technologies is beginning to have an important impact on the services sector, especially on that part which depends on digital information processing. In banking, the use of automated equipment able to communicate with each other is having a marked impact on the work of bank tellers, clerks and messengers, while at the same time facilitating the provision of new services, such as corporate management systems, and improving the reliability of existing ones. As a result of the increasing use of word processors, optical character recognition systems, and electronic mail and facsimile machines, routine activity in offices is changing. The growing use of point-of-sales terminals is beginning to affect the retailing and wholesaling sector. In all cases the productivity of labour is being raised markedly. The productivity of capital is also being raised, for although these new technologies often involve large initial investments (for example in computer network systems), increasing their production capacity (say by adding another terminal) is usually achieved at low marginal costs. The resultant economies of scale and versatility of much of the equipment concerned is also blurring the distinction between service and other industries. The effects on the telecommunications sector have been particularly important in increasing the international tradeability of services and, to a lesser extent, goods, and thus adding yet another dimension to the opportunities for growth by further integrating the global economy.

1.44 Other emerging technologies have as yet been less visible, but one of them—*biotechnology*—may be equally important. Indeed 'traditional' forms of biotechnology have already had profound effects on the agricultural sector in increasing productivity over a long period of time. 'Traditional' biotechnology has been basic to the development of the new high-yielding strains of cereal and other grains which have made possible the so-called 'green revolution' experienced in much of Asia during the last couple of decades. In the Indian state of Punjab, for example, average yields of wheat rose from 1.4 tonnes per hectare in 1966 to 2.2 tonnes in 1969 following the planting of high-yielding varieties. By 1972, only six years after the new varieties were introduced, farmers' real incomes had doubled. The use of 'modern' biotechnology is still too new to have generated concrete evidence of its effects on economic growth, but its applications not only in agriculture but also in industry (especially pharmaceuticals and chemicals), mining (through leaching), energy and services, referred to earlier, are likely to become very significant and have important spin-off effects. In some cases they involve techniques whose capital and operating costs are lower than those of more conventional technologies, and can thus assist developing countries to short-circuit more costly conventional methods.

1.45 Similar difficulties exist in adducing evidence of the effects on economic growth of new technologies for generating renewable energy and producing new industrial materials. But by making it possible to use widely available elements in an effective manner, their impact on growth, though unqualified as yet, is likely to become increasingly significant.

Employment

1.46 The employment impact of new technologies is one of the most crucial and politically sensitive. Despite its importance, however, there is considerable difficulty in evaluating it. There are several reasons for this. First, the negative impacts are often highly visible, since they are accompanied by factory closures and redundancies; the wider and longer-term effects are not so readily quantified, but are important to take account of the gains in employment resulting from increased demand (due to improved quality and/or lower price of the good or service).[11] Second, the impact of new technologies on employment is difficult to isolate from that of other factors, such as changing patterns of demand or international trade or economic policies; for example, whether job losses in the textile and clothing industries in the major developed countries have resulted from import competition from developing country suppliers, from the new technologies introduced by developed country producers themselves, or from an interaction between the two. Moreover, it could be argued that new technologies are in themselves almost certainly 'neutral' in their overall employment impact. The effect on aggregate employment, whether in terms of numbers employed or skills required, will depend on the way in which the technology is introduced and used, and in particular on the context of economic policy. Third, the quantitative studies which have been undertaken have been largely concerned with only a limited range of activities, notably those affected by developments in microelectronics. They have also generally been based on the experiences in the major developed countries, and there has been relatively little assessment of the implications for developing countries. These difficulties and different approaches to policy suggest a need for considerable caution in reaching conclusions about the employment impact of new technologies.

Levels of employment

1.47 The impact of technologies on levels of employment shows considerable variations, both between sectors in each country and within the same sector in different countries. We consider below some of the employment effects which have been studied in both developed and developing countries over a number of sectors (electronics, textiles and clothing, engineering, services, agriculture, and energy).

1.48 We have already noted that while the positive impact on employment of new technologies is hard to quantify, technological innovation is a necessary prerequisite to sustain economic growth, upon which increases in employment ultimately depend. There is also now some evidence from studies at the macro level which suggests a more positive result in employment terms.[12] But there is demonstrably technologically-induced labour displacement in specific firms and industries.

1.49 In the motor vehicle industry in developed countries, new technology has resulted in a significant shedding of labour. For instance, the introduction of an automated welding line at a car plant in Sweden reduced the number of welding jobs from 100 to 20, while it has been calculated that a fully computerised production line would reduce total employment at the plant from 1,030 to 50.[13] Similarly in a UK car plant the use of 28 robots in one operation cut the workforce from 138 to 38—on average each robot displaced 2.6 jobs.[14] In the Japanese car industry it was found that one robot had replaced between half and one worker per shift, depending on the process, with an average replacement of one-sixth of a worker. No workers were dismissed, however, although recruitment fell and the structure of the workforce therefore changed.[15] Further labour-shedding is expected, given suggestions that as much as 50 per cent of assembly work in US car plants could be done automatically. Other estimates suggest that it will be technically possible to replace almost all manual operatives in the automobile industry by the early 1990s and that similar developments could occur in the electrical equipment and metalworking industries.

1.50 The same trend is likely in some services such as banking, where the UK Clearing Bank Union predicts that automation will reduce employment in British clearing banks by 10 per cent during the next decade. Other studies, such as those undertaken by NORA of France,[16] suggest that new technologies will reduce the workforce in banking and insurance by as much as 30 per cent in the next ten years. Many aspects of employment in banking have already changed, even if the number of jobs have not been affected; for example, in the 1970s Citibank reduced its clerical staff from 10,000 to 6,000, the excess being absorbed in other work after retraining.[17]

1.51 While some negative impacts have already been experienced at sector level, there are others in which employment gains have occurred or are expected from new technologies. For example, one study estimated the overall impact of new technologies on the electronics sector itself in the United Kingdom would be to increase employment by 25–60,000 jobs in the period 1980 to 1995.[18] Employment in the services sector has continued to grow in areas such as computer software and social services, which have been considerably affected by the introduction of new technologies. A study on employment in office services within the OECD countries over the past few years suggests that while there may have been some moderation in the rate at which new staff are being recruited, there has been little visible evidence of any increase in job losses caused by new technologies.[19]

1.52 In the United States, nearly all the occupations with the highest forecast growth in employment in the 1980s are involved in information processing, and it is predicted that secretaries, typists and general office staff will be the source of the largest number of new jobs.[20] A recent Japanese study on the effects of office automation in 6,000 private sector enterprises showed that some 27 per cent had experienced a decline in numbers employed whereas 43 per cent had reported an increase. Of the information process businesses surveyed, only 4 per cent had reduced their workforce while 48 per cent had expanded it—and within this latter group 63 per cent cited office automation as a reason for the expansion. There has also been an increase in the number of specialised 'service' occupations within other sectors. There is, however, a growing disparity in the overall employment experience between the United States and Japan on one hand, and the West European economies on the other, which makes it necessary to treat single country studies with caution.

1.53 In the developing countries there has been less experience of emerging technologies, although there are a number of cases where these have already had effects. New biotechnology, for example, has enabled the use of immobilised enzyme techniques to produce high-fructose corn syrup which has indirectly displaced labour in cane sugar production and processing in several developing countries. It also enabled large multinationals to use genetic engineering to bypass the need for the steroid diosgenin,which Mexico used to produce from the barbasco plant. Negative employment effects on developing countries could also be experienced in mineral industries, following the development of new materials such as ceramics which could be substituted for base metals such as steel or aluminium, or by fibre-optics which is already eroding, albeit on a small scale so far, part of the copper market. It is moreover likely that where the new technologies reduce the advantages which developing countries have had in export-oriented labour-intensive production processes (a point we consider in greater detail below), there could be diminished opportunities for employment. Two product groups which are significant in terms of developing countries' employment, viz. production of garments and semi-conductors, are often cited as potentially threatened.

1.54 To set alongside the potential negative effects are others, more obviously positive. New technologies should offer increased employment opportunities for developing countries in the future. For example, in biotechnology the use in agriculture of new techniques such as protoplast fusion and genetic engineering should speed up the discovery of plant varieties with improved tolerance, say, to drought or soil salinity, and increased resistance to pests and pathogens. Such developments should facilitate employment in marginal lands without substantial inputs of expensive fertilizers. And where improved seeds have been introduced into improved agricultural systems, this has permitted major increases in activity based on multiple cropping. In the areas of India which have experienced 'green revolution' technology, labour shortages have emerged, generating a demand for migrant labour on a substantial scale.

1.55 The greater use of new and renewable sources of energy should have a positive net impact on employment in developing countries. Renewable energy is expected to create more jobs than would the same amount of energy obtained from fossil fuels or nuclear power. Jobs are created not only as a result of installing small-scale hydro plants, wind generators and wood burning stoves, but also in their construction or manufacture. Increased energy in the rural areas, which is where most of the population in the Third World still reside, can generate additional employment in such activities as crop growing and drying, agro-industries like food processing, handicrafts, and basic-needs production as in brick-making. In some instances one new technology can enhance another. Biotechnology, for example, can be used to promote the growth of fast-growing species of tree to produce biomass material for fuel.

1.56 Analyses of the impact of new technologies on jobs lead us to conclude that in the long term the major issues will centre less on the numbers employed—which are a function of economic rather than technological factors, and are in any event not meaningfully calculable in any aggregate sense—and more on the impact on the skills required, and consequently on training, retraining and the organisation of work. It is to this aspect that we now turn.

Skills

1.57 New technologies generate demands for new skills and make others obsolete. There are, of course, considerable variations between the experience of different sectors and countries, and at the level of the firm, on the manner in which work is organised, i.e. on the system for utilising the technology. Moreover, such 'system' or organisational considerations are of particular importance with the emerging technologies (where the speed of diffusion and nature of impact are less dependent on solving technical problems with the hardware than on the 'organisational' limitations of those applying them).

1.58 In very broad terms the demand for managerial and technical skills is increasing while that for the more physical and unskilled tasks is decreasing. In the electronics sector, for example, employment gains are concentrated in highly skilled categories (notably scientists and technologists but also managers and supervisors) and employment losses among operators and, to a lesser extent, artisans, as well as clerks. In the tool-making industry the use of CNC machine tools has radically changed the role of machinists. These were traditionally considered as highly skilled and requiring long training; the new technologies transfer the control of the machine from the operator to the computer systems specialist and reduce the machinist to a monitoring role. In engineering firms generally, new technologies have reduced the jobs in fabrication, assembly and inspection, while those in problem-solving, planning and coding tasks have grown in number and complexity. In the textiles and clothing industries the introduction of new technologies such as CAD/CAM, laser cutting or automated pressing techniques have reduced the demand for skilled 'blue-collar' workers, while other new technologies have also replaced many tasks formerly undertaken by the less skilled. The increasing use of automation has also resulted in reduced demand for skilled labour to exercise quality-control functions. On the other hand, in many of these industries, there is an increased demand for engineers to programme and maintain the new machinery, and for management with a greater awareness of the new technologies.

1.59 Similar patterns are apparent within the services sector. Banking, in common with most 'office' activities, consists of two broad groups of workers—those who create, analyse and interpret information and those who process it. While the provision of new services and improvement of existing ones may absorb present staff or even increase labour demand, the introduction of new systems has considerably reduced the number of manual operations and eliminated many routine clerical functions. Given that women workers are concentrated in these 'information manipulation' jobs (in many developed countries about a third of female labour is in the clerical field), they are likely to be particularly affected by these changes. Even within areas such as secretarial work new technologies are changing skill requirements, with word processing often modifying traditional secretarial activities by separating the typing from the administrative functions. These skill impacts may become more evident in future and are likely to vary considerably between countries.

1.60 A broad summary of the emerging trends in developed countries is contained in a European Community FAST[21] report. This suggests that between 1980 and 1995, managerial and technical workers will increase from 10 and 6 per cent of the workforce in manufacturing, to 20 to 40 per cent, respectively, whereas artisans, semi-skilled and unskilled workers will decline from 32 and 41 per cent of the workforce, to 15 and 10 per cent, respectively.

1.61 In the longer term even those currently categorised as 'skilled' or holding technical and managerial positions may be affected by the way in which new technological systems alter work organisation, particularly in terms of centralisation of management. The use of information technologies in activities as diverse as banking, industrial design and tourism, is leading to more streamlined decision making and production control, with a reduction in demand for traditional middle management capabilities. On the other hand, the new technologies have created new categories of skills (for example, in R & D, programming, process control and management), as well as introducing demands for such skills into sectors where previously they were not considered necessary (as in textiles).

1.62 Changes in the pattern of skills demanded can lead to bigger disparities in status, pay and security between groups of workers. The uneven impact of changes in demand affects three main categories of worker. First, as noted above, there may be a proportionately greater impact on women than on men. Women occupy many of the clerical or other jobs being replaced by automation, for example in the textiles and clothing industries, but they may also gain through the increasing proportion of jobs in the services sector. Second, there will be a particular impact on older workers who are less adaptable or less well placed to undertake retraining to acquire the new skills in demand. Third, there will be a general raising of the skill requirements for new entrants to the labour market, making school-leavers with little numeracy and technological awareness very difficult to employ. These impacts show the need to approach technological change from a broad social perspective rather than solely from the viewpoint of specific industries.

1.63 The impact of new technologies on skills also has important implications for developing countries. Some 'deskilling' may be beneficial to these countries by relieving the constraints of skill shortages, and there may thus be potential for 'leapfrogging' stages of the industrialisation process. It is however possible that this skill-saving could increase the disparities between the NICs and the other developing countries, since taking advantage of new technologies implies having the very sort of technically trained labour force and scientific infrastructure which most developing countries lack. In the short term, moreover, the skill requirement of many new technologies, particularly microelectronics and biotechnology, are such that diffusion of these technologies into sectors of importance to the development process may be restricted.

1.64 These changes in demand for skills, in both developed and developing countries, emphasise the importance of training and retraining, an issue pursued in the next chapter. While the new technologies make demands on the education and training systems (and will do so increasingly), they can also have a major impact on the training processes themselves. The lower costs and increasing flexibility of computer-based information technologies are making it easier to train more people. Training can be undertaken anywhere, for example at home or in the workplace or in decentralised locations (especially useful in the case of agricultural training), and at any time, thus providing for greater access. This may be of particular relevance to developing countries in dealing with skill deficiencies in the informal sector or among less educated farming communities if it can be appropriately 'blended' with traditional training and education in those sectors.

Working conditions

1.65 We consider the impact of new technologies on the general social environment in the following section; here we draw attention to their direct effects on working conditions. These can be broadly divided into two: those affecting the physical conditions of work and those affecting the organisation of work.

1.66 The effects of new technologies on physical working conditions are both positive and negative. They can lead to reductions of hazardous or tedious work and to a safer or cleaner environment; but they can also result in increased monotony, greater stress and other health problems. Positive effects include the automation of jobs in dangerous or unhealthy environments, conveyance of minerals and bulk chemicals; the improved reliability of machines; and the protection of workers involved in preparing potentially dangerous products. In Japan,[22] CNC machine tools and robots have often been introduced specifically for health and safety reasons in spot and arc welding, and materials handling.

1.67 On the other hand, the way in which some new technologies are used can exacerbate health and safety problems. An example is the massive growth in use of visual display units (VDUs)[23] which has been accompanied by a growing incidence of eye-strain, stress, fatigue, headaches and social/psychological problems caused by increasing isolation among users. The expansion of nuclear power provides another example, as each stage of the production chain can involve dangers not only for the workers directly involved but also, potentially, for society as a whole. New technologies can also increase some familiar problems associated with boring and repetitive tasks. A UK Government report[24] noted the potential for robotics to lead to boredom and the careless use of existing machinery, with ensuing accidents.

1.68 Some of these problems are also likely to be experienced in developing countries, where the quality of the working environment has often received relatively low priority. New technologies offer these countries many opportunities to enhance the working environment, through reducing drudgery and tedium, and enhancing health and safety. But difficulties may be exacerbated where the technologies are imported from developed countries and are not adapted to local conditions, causing mechanical breakdown and accidents. There are also problems where 'dirty' industries or production processes, no longer acceptable in industrial countries, are transferred to developing countries. Apart from traditional 'smokestack' industries such as smelting, or special cases like asbestos, the fabrication of semiconductor chips in conditions hazardous for health is an often cited example among new technologies. Even among modern technologies which are reasonably well understood, potentially grave dangers may exist if operations are inadequately supervised or monitored—as the recent example in Bhopal (India) so tragically showed.

1.69 New technologies also influence the working environment by modifying the organisation of production. The spread of information technologies has the potential both for greater centralisation of decision-making and for greater dispersion of production. As technical advances have reduced costs and increased the power of computers, terminals have become more widespread within organisations. Information systems offer the potential for remote-site working ('tele-travail'), which could result in the increased geographical dispersion of corporate units of activity, including possibilities for home-working for 'office' and other 'service' workers. Similarly in manufacturing, where it has been suggested, for example, that the use of CAD/CAM in, say, automobiles or textiles could result in all designs being undertaking in one country and production in another, to take advantage of availabilities of labour or raw materials. On the other hand, there have also been instances of greater centralisation of work, involving the linking of previously separate spheres of activity, and the relocation of supply-input firms to cluster nearer to production plants, so as to exploit the 'systems gains' made possible by microelectronics.[25] It is too early to assess which trend is more important, but what is already clear is that new technologies are blurring the distinction between previously separate activities, in services as well as in manufacturing.

1.70 New technologies undoubtedly increase the potential flexibility of production systems and work patterns. They can enhance job satisfaction and make fuller use of workers' skills. But they may not be introduced in such a way as to do so. Workers often express concern about fragmentation of jobs, isolation from other workers, heavier workloads, less interesting work, loss of discretion and absence of participation. A detailed survey[26] of a major German company showed that, in general, workers replaced by robots were moved to jobs which involved neither an upgrading in skills nor any other type of enhancement, and that the conditions of the others deteriorated in several ways: intensified workloads; reduced job content at individual machines where the only tasks remaining consisted of the simple handling of materials; smaller areas of discretion and decision; less opportunities for personal contacts; growing monotony; and increased control and supervision. No doubt counter-examples could be found but the case illustrates the more general point that the effects of new technologies depend not only on their fundamental properties but on the way in which they are introduced into particular firms, industries or societies.

1.71 Closely related to the impact of new technologies on work organisation is that on industrial relations. New technologies have not only begun to cause a reshaping of trade unions in terms of numbers and types of workers represented, but they have also resulted in considerable changes in the issues being faced by both unions and management. These issues include training and retraining, avoidance of polarisation of the labour force, health and safety directly related to the introduction of new technologies, and also longer-term questions such as job creation, increased worker participation, formation of joint objectives and shared responsibilities. The demand for adequate consultation when new technologies are introduced is an increasingly important focus of labour relations.

1.72 Another such area is caused by the increasing use of data information networks by firms or governments to supervise employees at their places of work. 'Intelligent terminals' and other automatic units, including cash registers, word processors and CNC machine tools, allow information to be collected on employees' performance, such as time spent at the machine, work speed, error rate, etc., which can lead to closer monitoring and hence more rigid control over the pace of work. This technology also enables the centralised collection and storage of other information (for example on trade union activities) on computerised personnel records. Workers' organisations have sought agreements to regulate the collection and use of this type of personal information.

1.73 Most of the above issues have so far been largely confined to the industrial countries. While they have had generally little relevance, as yet, to employment in developing countries with large informal or subsistence agricultural sectors, it is inevitable that the introduction of new technologies into those countries will bring the need for them, too, to address similar problems in future.

International trade

1.74 In this section we analyse the impact of new technologies on international trade, first reviewing briefly the conceptual issues and then examining the trends for particular goods and services.

1.75 New technologies have been of major concern to traders in developing and developed countries alike, often from opposing standpoints. Raw material exporters face the prospect of increasing competition from substitutes developed with new technologies, especially biotechnology and new materials technologies. In manufacturing, two factors may inhibit the continuing expansion of developing country exports. One is the reduction in importance of labour costs as a result of process innovations, which is likely to deter the relocation of industries from developed to developing countries, or to lead previously labour-intensive industries to migrate back to developed countries. The other is the rapid generation, in some industries, of new and better products, causing product cycles to become shorter and so offering less scope for production processes to mature and be transferred to developing countries before products become obsolete. In the developed countries, on the other hand, manufacturers are concerned that failure to introduce new technologies fast enough will affect their competitiveness, resulting in more jobs being lost than would have been directly displaced by the new technologies.

1.76 An underlying problem in analysing trends, however, is the difficulty in separating the effects of new technologies from those of other factors. In particular, government fiscal and financial incentives, cheap raw material, energy and other inputs, where these are available, 'start up' and 'sunk' costs, as well as preferential access for some exports to developed countries, all act as a brake on any movement back to developed country locations. Protectionism, on the other hand, both in the form of restrictions on access to developed country markets and on technology exports to developing countries, acts in an opposite sense. These broad trends can be illustrated with reference to specific industries.

1.77 In the *electronics* sector, extensive product innovations, coupled with process innovations to cut costs and enhance technical characteristics, have combined with a rapid expansion of international specialisation to produce a substantial growth in world trade, of which an increasing share now originates in developing countries. The latter's predominant interest in the late 1960s and early 1970s was in consumer electronics but more recently they have become involved in industrial electronics which are more technologically complex. China (Taiwan), South Korea, Singapore and Hong Kong have investments planned which should make them leading exporters of computer parts and peripheral equipment (specialising in terminals, monitors, disk drives and personal computers), with exports of some $1 billion each by 1990 compared to less than $300 million each in 1982. Although these four countries account for the bulk of developing country electronics' exports, a second tier of exporters has emerged including Malaysia, Brazil, Thailand, Indonesia, Argentina and the Philippines. The latter group's primary interest is in traditional consumer electronics—items which have been 'cast-off' by more advanced producers in developed countries and in the four NICs mentioned above—but they are also involved in the production of some high-tech items such as computer components, and in assembly and final testing.

1.78 The expansion of these industries in developing countries partly reflects the highly competitive nature of the world market, forcing manufacturers to seek lowest cost locations. In the Asian NICs, wages of assembly workers and skilled engineers are well below US levels (though the differentials are falling) and other input costs (such as electronic components, machine stamping, precision tooling) are frequently up to 60 per cent cheaper than in most developed countries, while infrastructure is often subsidised. Moreover they have the advantage (for manufacturers) of less rigid control over working conditions, allowing longer working hours (and so higher capacity utilisation), and less resistance to new work methods than in many developed countries. Domestic firms may also have an advantage over transnational corporations (TNCs) in the production of some new items, for which the efficient scale is relatively low, as their greater operational flexibility allows them to anticipate and respond promptly to market demands.

1.79 Few other developing countries offer similar attractions, and this is reflected in their low share of world electronics exports. Rapid technological change would appear to be increasing the barriers to their entry, at least into the high-tech end of the market. For example, in the world semiconductor market, which is becoming highly competitive, R & D costs have risen steadily, as have investment costs and the minimum efficient scale of production,[27] while new technologies have reduced the importance of unskilled labour costs. For many poorer developing countries with limited infrastructure and shortages of skilled labour, production costs may actually be higher than in the developed countries. Nonetheless there may still be some market niches for products which are suitable for this group of countries to produce for export, including relatively mature (and still labour-intensive) items such as radios or pocket calculators. But there is always the possibility that further product or process innovations will remove even this area of comparative advantage.

1.80 There have probably already been some instances of developed country electronics capacity being expanded at the expense of developing country exports. For example some leading US TNCs have set up highly automated very large-scale integrated chip assembly and testing plants onshore. These are sometimes used as part of the product development process—allowing new systems to be tested and teething problems solved before they are transferred to offshore sites. But in general it seems that semiconductor production offshore has not kept pace with technological changes in the industry as a whole, so that although exports from offshore plants have continued to grow, their share of the more sophisticated products has fallen.

1.81 Protectionism has also been a catalyst for relocation of production back to developed countries. The European Community industry has been lobbying for the imposition of a 14 per cent tariff on imports of audio and video equipment (instead of the present level of 5 to 8 per cent) for three years to allow for restructuring. It also wants a 19 per cent 'infant industry' tariff for new products—as it already has for compact disc audio systems. This trend, coupled with the imposition of quantity restrictions in various guises ('voluntary' export restraints, 'orderly' marketing arrangements) on imports of several products (for example VCRs) from South Korea and Japan, has led many TNCs to set up plants in Western Europe which might otherwise have been located in South-east Asia, if not in Japan itself. Technological protectionism—embodying various forms of restriction on the export of technology—is a further factor inhibiting the diffusion of technology and the options available to developing countries.

1.82 How far future generations of technologies will affect the second-tier countries, or even the NICs, is unclear. For instance it could be argued that with extensive investments in foreign plants, worldwide marketing networks and a particular organistion of management, TNCs are unlikely to retreat to less internationalised patterns of manufacturing electronics goods. But even if they do so, the new technologies could still have a significant effect. Indeed there will be increasing pressure on producers in these countries to automate various processes in order to maintain their competitiveness with those in the developed countries; in other words, although automation may not affect the volume of exports it will almost certainly lead to job losses in particular sectors of these industries, unless output increases more than proportionately. The industries' organisation may also be affected in the sense that domestic manufacturers find it increasingly difficult to operate independently—i.e. to obtain the appropriate technology and components or to market their products without some liaison with foreign companies, both the technology producers and the end-users. The development of a systems approach towards production is likely to reinforce the need for increasingly close contact between developing country exporters and end-users.

1.83 The impact of new technologies on trade in *textiles and clothing* is a major concern of developing countries, particularly the less developed for whom the two industries are often a crucial first step in the process of export-led industrialisation. In 1982 textiles and clothing constituted 26 per cent of manufactured exports from non-oil developing countries (compared to 34 per cent in 1973) and 11 per cent of total exports (12 per cent in 1973). Their share might have been even greater had it not been for quantity restrictions under the Multifibre Arrangement, which has constrained the growth in developing country exports, contributing to an absolute decline in value terms in 1982.

1.84 There is evidence that the use of microelectronics-based techniques (such as CAD and automated cutting) has led to some textile processes (grading, cutting, knitting, toe-closing) being relocated to developed countries. But the extent of this relocation has been limited: first, by the fragmented nature of the industries, particularly clothing; and secondly, by the technical difficulties of automating garment assembly operations. However it has been suggested that in the long term two developments will threaten developing country export prospects. The first is the development of FMS, including automation of all assembly stages, by the end of the 1990s (Japan envisages having a prototype available by 1987 and in commercial use by 1989). The second is the increasing diffusion of such systems because of an increasing concentration of the industry and a fall in FMS unit costs as economies of scale in production make them available to medium-sized firms.

1.85 Developing country exporters can react in various ways. The relatively gradual nature of these technological changes in the developed countries should allow some restructuring and possibly retooling of the developing countries' industries. Some already use high-tech equipment, but generally on a limited scale. For example it is estimated that between them the NICs possess no more than ten CAD units and two automated cutters. Slightly greater use is made of dedicated electronically controlled units, such as pocket setters, and programmable sewing machines, particularly by firms producing for export. There may be scope for raising the number of CAD units in the Asian NICs, especially if time-sharing bureaux are set up. Certainly, for the NICs, increasing competition from lower wage developing countries on the one hand, and quasi-automated developed country firms on the other, is likely to justify the adoption of high-tech methods as a means of preserving export markets even if this is at the expense of some employment.

1.86 For most other developing countries, however, the economic arguments for automation are less convincing—although it might help to relieve various skill shortages and to upgrade quality. In any event, lack of the necessary techno-managerial capacity, coupled with low wage levels and volumes of production, make automation on any scale unlikely. Moreover, with protectionism there will be little opportunity for these countries to produce on a large enough scale to justify investment in new technology. In the short to medium term they will probably maintain their comparative advantage in fashion garments, for which production runs are short, with frequent changes of style. But in the longer term, FMS may become so flexible as to be economical even for short production runs. The smaller developing country exporters may therefore expect to have a continuing need to search out new niches in the garment market and to raise productivity; this is all the more reason for their being allowed to diversify exports without facing protectionist restrictions.

1.87 There is little statistical evidence as yet that new technologies are affecting the pattern of world trade in *engineering products*. Exports from the NICs have continued to grow both absolutely and as a share of the world total. But exports from developing countries as a whole fell from 1980 to 1983, after rapid growth in the 1970s, reflecting the recent recession and possibly some loss of competitiveness, which might have been due to a widening technological gap with other exporters, as much as to other factors. Nonetheless it is clear that microelectronics-based process innovations, such as CAD, the incorporation of microelectronics into products, such as CNC tools, and the use of new materials, such as ceramics or optical fibres, may have important implications for the world's engineering trade. First, exporters of conventional equipment, notably lathes, may be faced with falling demand for their goods as the new equipment absorbs an increasing share of the market.[28] Secondly, firms using conventional equipment or materials to manufacture tradeable goods may be forced to upgrade them in order to remain competitive in price and quality. If these technologies are not available domestically, imports will be needed, possibly as part of a foreign investment package.

1.88 In the short term it seems that the equipment typically exported from developing countries will continue to command an important (though shrinking) share of the market for engineering goods, with sales falling in absolute terms to the developed country markets but rising elsewhere. Their exports may even rise if developed country producers specialise in high-tech tools and move production of older or 'lower' technology equipment to developing countries, as major Japanese machine-tool builders have been doing.[29] There may also be opportunities for increased trade in such goods among developing countries themselves.

1.89 The market for high-tech equipment itself appears to be both highly competitive, and to have a number of barriers which only the NICs are likely to overcome in the medium term. In some cases the minimum efficient scale of production is growing—scale may even be more important than wage levels, as the share of labour in total costs is falling. Another major barrier is the need for a domestic capability in electronics design, engineering, and R & D. Finally there is the issue of strengthening links between producers and users of sophisticated equipment which requires the support of an international marketing and after-sales network. For example CNC lathes, which are mostly produced in developed countries, are substitutes for engine lathes, in which NICs have specialised. A number of NICs have begun to produce cheap, fairly standardised CNC lathes, but they have experienced problems. Few of them have sufficient output to realise economies of scale; others lack the necessary design personnel and sales staff, and are unwilling to take them on without government support in what is an unknown and therefore risky market.[30]

1.90 With regard to the use of engineering equipment to manufacture tradeable goods, such as cars (and car parts), it seems that developing country manufacturers are coming under pressure to update their plant in order to remain competitive. Unless they do so, the current technological upheaval in the car industry (for example involving increasing automation and a shift from an electro-mechanical base to an electronic-plastics one) is likely to restrict their participation in the internationalisation ('world-sourcing') of production. In Japan the extensive use of CNC machine tools and robots, together with continuous product innovation as well as the 'just-in-time' system of work organisation, mean that costs are lower even than in South Korea, where wages were a seventh of Japanese levels in 1980.[31] There has been some relocation of Japanese and US production to the NICs but this has been primarily to circumvent market access problems rather than because of technological factors. In the production of car components, in particular so-called major mechanicals, extensive automation requiring large initial investments has restricted market entry to a few countries like South Korea. 'Minor mechanicals' are most suited to low wage sourcing and yet they are also most open to automation, thereby putting their future as a developing country export industry at risk.

1.91 For the *service* industries, the extensive application of information technology, more than other new technologies, has important implications for their location worldwide and hence for trade in services. Traditionally trade in services has had two distinctive features: first, it has accounted for a very small proportion of world output of services,[32] and secondly, such trade as has occurred has been dominated by the developed countries, both as exporters and importers. Initial evidence suggests that the new ways of handling information coupled with improvements in telecommunications (satellite transmission, digital networks) are likely to undermine the first feature, by increasing the tradeability of services. For example, banking and insurance services or an entire library may now be transported from a terminal in one country to a terminal in another. The question is whether this will reinforce developed countries' dominance in services trade. The implications for non-services trade also need to be considered.

1.92 Cheaper communications would appear to have stimulated the establishment of new export-oriented service industries in a number of developing countries. For example the United States now imports computer key punching services from Barbados, South Korea and the Philippines, computer software services from India and Pakistan, and typesetting and editing services from South Korea.[33] Most such computer-related exports are relatively simple tasks undertaken on behalf of TNCs. There seem to be few entry barriers for developing country firms—the capital costs are low and there are many niches open to small firms. But the need to have close contacts with foreign software users, if they wish to do more complex tasks independently of TNCs, may cause difficulties. Close contact with customers is essential too, in order to gain an understanding of the products or processes (systems) for which the software is being written. This may only be possible if developing country firms set up subsidiaries in their potential export markets. It may also help them break into the market for maintenance and servicing which is likely to be the biggest of all software markets.

1.93 At the same time it is possible that the new technologies, by creating barriers to market entry, could adversely affect imports from developing country service industries. For example, countries which are not able to get information about their tourist resorts onto any of the tourist industry data networks may find that some of their trade is diverted to others. This is likely to reinforce the dominance of hotels owned (or tours run) by TNCs whose integrated purchasing, management and marketing networks, strengthened by the new information technology, as well as often integrated ownership with airlines, already present significant entry barriers to locally owned firms in developing countries.[34]

1.94 Whatever increases in developing country exports occur, they are likely to be outweighed by the growth in imports of services from developed countries. Such imports include both well-established services, such as banking, insurance and reinsurance, brokerage, accounting, advertising, engineering (construction design and repairs) and printing, which have now become more 'transportable'; and new services, such as data processing and transmission (of commodity, stock and other financial statistics), which have been created by information technology. There is already evidence that falling telecommunication costs have led firms in developing countries to have their designs, calculations and routine research data processed in developed countries.[35]

1.95 Some sources have suggested that new services technologies are also likely to have a considerable effect on merchandise trade. With the growing links beween the services sector and industrial development, the state of services infrastructure will increasingly be a determinant of comparative advantage. And notwithstanding the inroads some developing countries might make in one field or another, the overall situation is one of a growing gap vis-a-vis the developed countries in terms of the material base and infrastructure necessary to support 'information-intensive' high value-added services and industries.

1.96 In the case of raw materials and *foodstuffs*, the increasing use of biotechnology (and new energy sources) is a source of anxiety to many traditional exporters, both developed and developing. The corollary is the prospect of efficient import substitution in such areas as energy and food. For example, the development of high-yielding varieties (HYVs) of wheat and rice—in conjunction with a package of supporting policies, including higher prices for farmers—has led to substantially higher growth in output. This is especially so in Asia where their use is widespread, with HYVs accounting for more than 70 per cent of the area under wheat and 40 per cent of that under rice. HYVs were primarily responsible for transforming India from being the world's second largest grain importer in 1966 to self-sufficiency by the late 1970s. One factor retarding the diffusion of HYVs has been the associated need for inputs such as irrigation and (imported) fertilizers and pesticides. It is expected that with the latest genetic engineering techniques—for example the incorporation of nitrogen fixing or resistance to insects—new seed varieties may be available by the end of this century which will make food production less dependent on such inputs. At the same time the use of such techniques to raise the nutritional value of domestically produced foods will reduce the need for imports in existing food deficit countries.

1.97 Other *primary commodity producers* are also likely to find their export earnings affected by developments in biotechnology which are leading to the increased use of synthetics or substitutes in their export markets. For example immobilised enzyme technology has led to the extensive use of high fructose corn syrup, which has an estimated 10 per cent of the world sweetener market in 1985 (45 per cent in the USA). Genetic engineering has allowed firms in developed countries to produce some medicinal chemicals (including steroids), pesticides, flavourings and essential oils (for example, clove oil) from tissue cultures rather than from plants traditionally exported by developing countries. The latter may, however, respond by incorporating some of these new techniques to diversify output or improve the quality or lower the cost of their exports. For example, Malaysia is using plant cloning propagation as a means of shortening the time before its rubber trees mature, thereby increasing the competitiveness of its natural rubber exports vis-a-vis synthetic rubber.

1.98 New *energy* technologies have focused on the development of new, indigenous, sources of energy (frequently renewable) as well as economising on energy use. Both are critical for freeing resources for development, at least in non-oil exporting developing countries, 31 per cent of whose export earnings in 1982 were spent on fuel imports (compared to 13 per cent in 1973). In Brazil one of the main incentives to develop the use of ethanol as a fuel has been to cut the country's dependence on imports; by 1985, ethanol production had reached the equivalent of 120,000 barrels of oil per day, saving the country $1 billion annually. Such savings are gross—in addition it is necessary to take into account the opportunity cost of producing the feedstock (including the land on which it was grown) which might otherwise have generated foreign exchange; whether imported inputs are needed in ethanol production; and other factors such as the impact on demand for imported engines, given the problems of corrosion with ethanol use. In many of the poorer African countries traditional renewable sources such as firewood already account for 70 per cent to 90 per cent of energy supplies and there is little scope for increasing their use, partly because of existing levels of deforestation, so that imports have become the major source of marginal energy supplies. It is all the more important for them, therefore, that new forms and sources of renewable energy are developed.

1.99 In *conclusion*, the new technologies clearly present a major challenge to developing countries, in many cases weakening their comparative advantage in the production of traditionally labour-intensive goods. Only the more industrially advanced of these countries may be able to respond by updating their technologies—and even then their efforts may be hampered by restrictions on technology transfer and rapidly changing technologies. The likelihood of new technologies leading to slower growth in developing country exports overall, let alone to a large-scale relocation of production back to developed countries, should not be overstated. For the poorer developing countries, however, there is a danger of being left behind—unable to respond to technological changes which threaten some of their exports or to create new opportunities. Much of the impact of new technologies on trade will, like its other impacts, depend on the 'environment' in which the technologies are introduced. Two main factors, which have been reflected in the industry examples above, are the government policies of the country introducing the technology (and particularly the development of its indigenous technological capacity) and the degree of protectionism facing the resultant goods or services.

Social matters

Organisation of society

1.100 Past experience has shown that the utilisation of any major new technology results in fundamental changes in countries' economic and social structures. Such changes are both a prerequisite to the full exploitation by society of a technology and a result of adjustment to its effects. Thus organisational structures develop in parallel with technology. This is most clearly evident in the case of microelectronics and associated 'information technologies', and it is likely that the structures needed to facilitate and support an 'information society' will be significantly different from those developed for a less automated, predominantly 'industrial society', or for the dual-economy type of society of many developing countries.

1.101 As we have shown above,[36] societies in developed countries are already beginning to experience the major organisational, or 'systems', changes which arise from linking individual automated operations and bringing together different types of technologies to exploit their synergetic effects (such as the use of computers in biotechnology).

1.102 'Information technologies' could be used in this way to have a centralising influence on decision-making in governments and firms.

This has led to concerns over the possibility of greatly increased central control and of mass surveillance. That such concerns have not so far been justified is partly because the technologies have also facilitated better communication within decentralised organisational structures. One example is the way in which 'information technologies' can facilitate coordination between institutions in administrative, academic and other fields which are characterised at present by segregation according to discipline.

1.103 Another possibility—and one which in many ways leads in the opposite direction—is the potential offered by other emerging technologies for the locational decentralisation of society. This could be vital in reversing the urban drift in developing countries. Renewable energy technologies may help in this respect, being usually small-scale, widely diffused geographically and often particularly suitable for the energy needs of rural communities. New biotechnology may also help to reinforce decentralised patterns of productive activity, in that it has the potential to boost agricultural yields, extend crop zones, and improve services, such as medical and veterinary care, to rural communities.

1.104 A further implication for the organisation of society relates to the effects of new technologies on the time spent at work and on other activities. It is expected that increasing productivity will lead to reductions in working time, both in terms of hours of work per day or week and in the length of the working life: in other words, longer periods on holiday and in education and (re)training, and earlier retirement, than would otherwise have occurred. As productivity has increased and incomes have risen above basic needs requirements, there has been a tendency to trade off higher incomes against increased leisure time. Over the past 100 years, the average duration of a lifetime's work for male workers in industrial countries has been lowered by almost 60 per cent, and it has been calculated that this might be reduced by a further 20 per cent by the year 2001 if similar trends in productivity and working hours as experienced during the 1960s and early 1970s continued to the end of the century.[37] If such trends are maintained, the challenges facing these societies in the longer term will relate not only to income distribution, but also to devising sufficient socially beneficial activities (as opposed to 'work') to fill peoples' time and give them a sense of self-worth and satisfaction. Education systems will have to reflect these trends.

Health

1.105 The qualitative impact of technological change in the working environment, including the health and safety of workers, has already been discussed. The benefits and risks new technologies present to the health of society as a whole are not altogether dissimilar to those faced at the work-place. New products and processes may have unpredictable and unintended side-effects on consumers, or may have external effects on the environment. New biotechnology has great potential for improving medicine and food supplies, which can contribute to improvements in health and increases in longevity. But it is feared that genetic-engineering could present dangers to the health and safety of plant and animal life. In another field, operational experiences have highlighted the health and safety concerns connected with nuclear energy production and use. Most industrial countries have therefore developed strict standards for testing new products and processes. At the same time, they are aware of the need to strike a balance between ensuring the safety of new products, such as drugs, and minimising obstacles to the innovation process.

Privacy and security

1.106 We have already discussed the implications of information technology for workers, but there are wider issues of personal privacy. Computerised information on individuals' health and education, social security, creditworthiness, motoring and criminal activities is collected and stored. All give rise to potential misuse, either deliberately or inadvertently. One example is the widespread practice in developed countries of selling files on creditworthiness. But is is computerised files on allegedly criminal activity, including what might be described as 'speculative files', which have raised most public concern; and the fact that telephone tapping has become easier with the introduction of electronic switching systems has exacerbated such fears.

1.107 Concern with these matters has led many industrial countries to enact privacy legislation or data protection laws. Such legislation varies considerably in scope. The United Kingdom, for example, only regulates the collection of information by public authorities, but some other countries, such as Sweden, have more comprehensive coverage. Most of the existing legislation has sought to regulate two opposing aspects of the problem. On the one hand, laws have specified individuals' rights of security and confidentiality with regard to information collected about them. On the other hand, laws have also specified the rights of access which individuals have to information collected on them. However, such laws have tended to cover the procedures by which information is collected and stored, rather than to specify the types of information or purposes for which it can be legitimately collected. This has led to doubts about the effectiveness of data protection legislation.

1.108 With the merging of computer and telecommunications technologies, privacy matters have developed an international dimension, since the possibility exists of collecting information in one country and transmitting it to another as a means of circumventing national data protection legislation. The increase in transborder data flows has led several international organisations, such as the EEC and OECD, to develop initiatives for harmonizing national measures relating to data protection.

1.109 Information technologies have other implications for national and corporate security. Data considered confidential in one country may not be so in another. As a result, the concerns of some national governments have led them to attempt to regulate transborder data flows to ensure that data of importance to national security are kept and processed within national frontiers. Developing countries have been particularly concerned with the enhanced capacity of TNCs to collect and transfer information about their economies. Information technologies also present opportunities for large-scale commercial crime, and the number of cases of fraudulent use of computer systems in the banking system has been rising. Such crimes may take a long time to be revealed and be hard to trace. If the central operating programme of a computer system can be subverted, then the security or accuracy of none of its reports can be relied upon. Corporations (particularly banks) have invested considerable sums in trying to protect their systems against fraud. Similarly, these technologies provide opportunities for circumventing copyright where information is stored in data banks providing remote access.[38]

1.110 With further technological development, many countries have become increasingly vulnerable, especially in their dependence on particular technologies; for example, those relating to energy supplies, where a power failure can produce severe problems in a conurbation. Similar problems are arising with the spread of integrated information networks. Such systems are vulnerable to breakdowns and the provision of backup may be either impractical or negate cost advantages. Systems may be open to the risk of breakdown for technical reasons, or as the result of sabotage. Remote centres for storing computer files could become prime targets for terrorists or criminals. Several such attacks have already been made on computer centres in France.

1.111 The increasing expenditure on arms and the technological sophistication of military equipment pose additional threats to security. The risk of accidental nuclear war may be increased with the greater reliance on fully automated computerised early-warning and counter-attack systems.

1.112 Finally, the advent of satellite telecommunications networks and data communications systems are likely to have several other impacts.

They may enable countries to share each other's vast stores of accumulated experience and information, and enhance their educational facilities. On the other hand, there is concern in some developing countries that exposure to foreign mass media constitutes a threat to their cultural identity, especially when they do not have the capacity to relay equivalent information about themselves and in a form in which they see themselves.

Physical environment

1.113 Technology can have a marked impact on the physical environment. In the past, technologies have removed some environmental hazards, but created others. As to the latter, there has been increased pollution and the loss of plant and forest cover. In developing countries, soil depletion and erosion, and lowered rainfall patterns and water-tables, leading in some cases to desertification, have resulted from the over-exploitation of natural resources in meeting the farming, forestry and fuelwood needs of growing populations at home and abroad. In addition, rapidly expanding unplanned urbanisation has caused deterioration in the environment in and around many major cities, especially in the Third World.

1.114 The major emerging technologies appear, however, to be relatively less intensive in their use of depletable natural resources, partly because of the greater control which microelectronics technologies allows over production processes. Certain applications of these technologies may nevertheless increase environmental risks. We have already referred to the environmental problems resulting from the relocation of 'dirty' industries or production processes to developing countries when they are no longer acceptable in developed countries. Among the emerging technologies, one example is of electromagnetic radiation from certain microelectronic products and toxic wastes from some processes in the semiconductor industry. Most renewable energy sources do not have the polluting emissions of fossil fuels (biomass and fuelwood are exceptions) or present such serious potential hazards as nuclear power. But reservoirs for large-scale hydro-electricity generation often destroy useful farm and forest land and animal habitats, as well as causing soil erosion; and the structures for large-scale wind-turbines may be visually intrusive and cause unacceptable noise levels. Other sources have other problems: for example, the production of hydrogen sulphide associated with the use of geothermal energy. New biotechnology also presents certain hazards, like the possible escape into the environment of micro-organisms harmful to plant and animal life. But more important, it may help to reduce the degradation of farm land caused by the support requirements of more conventional agriculture.[39] For the new plant varieties derived through new biotechnology will be genetically engineered to have increased resistance to disease and climatic variations and to have the capacity to fix their own nitrogen. They will not therefore require such large inputs of fertilizers, pesticides and other aids.

1.115 While we have indicated above the likely broad pattern of the environmental impact of new technologies, it should be remembered that some of these effects can be averted, or at least ameliorated, by government regulation and control, since it is the mechanisms whereby technological choices are made which largely determine the environmental effects, rather than the technologies themselves. Assessments have suggested that in applying technologies, a number of alternatives exist, with quite different environmental effects.

NOTES*

1. For definition and amplification of technical terms, see glossary (Appendix 1).
2. The microelectronics industry is dominated by the United States, which accounted for almost three-fifths of world computer production in 1981; other countries' production is small by comparison, but that in Japan has grown fast and by 1981 accounted for over an eighth of the total. (Source: US, *International Outlook*, 1983; data exclude production in socialist countries.)
3. See glossary (Appendix 1).
4. See glossary (Appendix 1).
5. Renewable sources of energy are estimated to account for around 20 per cent of all energy consumed in the world, 6 per cent in the developed countries and some 25 per cent in the developing countries (excluding large-scale hydro, the proportions would be about 15 per cent, one to two per cent and 20 per cent respectively). In most poorer developing countries, renewables account for half to three-quarters of the total, and in individual cases the proportions can be even higher—between 70 and 90 per cent in certain African countries.
6. Estimates of that portion of macro-economic growth attributable to technical progress (and other 'residual' factors) have ranged from seven-eighths in the case of the US non-farm sector during 1909–49 to between two-fifths and three-quarters in certain OECD countries during 1950–62, between three-fifths and two-thirds in Japan during 1955–64, and between one-quarter and one-third in

* In those cases where only abbreviated references are given here to works cited, complete references will be found in Volume II, Appendix 10, Selected Bibliography.

Australia during 1950–74. (See R. Solow, 'Technical Change and the Aggregate Production Function', *Review of Economics and Statistics*, August 1967; E. Denison, *Why Growth Rates Differ*, Washington DC: Brookings, 1967; and W. Kasper, *Technological Change and Economic Growth*, in Myers (1980).)

7. See country submissions in OECD (1984).
8. The school of thought emphasising technology in explaining long-term economic cycles is exemplified by Schumpeter; other adherents include Freeman, Clark and Soete. Economists putting the main emphasis on aggregate demand, especially for capital goods, and considering technological innovation to be secondary, include Schmookler, and Graham and Senge. (See Freeman, Clark and Soete (1982).)
9. K. Hoffman, 'Clothing, Chips and Competitive Advantage: The Impact of Microelectronics on Trade and Production in the Garment Industry', in Hoffman, ed. (1985).
10. See paragraphs 1.85 and 1.86.
11. ILO Advisory Committee on Technology (1985/II).
12. These studies of the British and US economies are, however, static analyses and therefore have obvious methodological limitations.
13. J. Evans, *The Impact of Microelectronics on Employment in Western Europe in the 1980s*, Brussels: ETUI, 1980, p. 86.
14. Evans (forthcoming) p. 16.
15. Watanabe (1984) p. 39. Roughly half of the robots were found to replace other machinery rather than labour.
16. Quoted in ILO, *Social and Labour Bulletin*, Geneva, No. 1/84.
17. ILO (1985/II) p. 34.
18. Soete and Dosi (1983).
19. Werneke (1983).
20. US Department of Labour, *Monthly Review*, August 1981.
21. European Community, FAST Series, No. 16, *Potential of Information Technology for Job Creation*, Brussels: 1983.
22. Watanabe (1984).
23. Currently there are more than 10 million VDUs in use in the USA alone, and it is estimated that by 1990 half the workforce in industrial countries will use VDUs. (Evans (forthcoming).)
24. Sleigh et al. (1979).
25. What Kaplinsky has referred to as an evolution towards 'systemofacture' in industry. (See R. Kaplinsky, 'Electronics-based Automation Technologies and the Onset of Systemofacture: Implications for Third World Industrialisation', in Hoffman, ed. (1985).)
26. R. Schneider, in CEDEFOP, *Final Report of Robotics Developments and Future Applications Meeting*, Berlin, 1983.
27. According to Truel (1980), the minimum investment required for semiconductor production rose from $2 million in 1972 to $60 million in 1982.

28. Suppliers to the engineering industry of traditional materials are also likely to find their export market shrinking, though so far the effect appears marginal—for instance, optical fibres can only substitute for the 3 per cent of world copper output traditionally absorbed by the telecommunications industry.
29. Watanabe (1984) p. 73.
30. S. Jacobsson, 'Technical Change and Industrial Policy: The Case of Computer Numerically Controlled Lathes in Argentina, Korea and Taiwan', in Hoffman, ed. (1985).
31. D. Jones and J. Womack, 'Developing Countries and the Future of the Automobile Industry', in Hoffman, ed. (1985).
32. Eight per cent in 1980 compared to the 45 per cent of world agricultural output which is traded and the 55 per cent of mining and manufacturing.
33. US Government, *National Study on Trade in Services*, Washington DC, 1983, p. 21.
34. UN, *Transnational Corporations in International Tourism*, New York, 1982.
35. Rada (1982, ID/WG.372/5).
36. See paragraph 1.69.
37. Sir Bruce Williams, *Technical Change and the Work Ethic*, the 1983 Brough Lecture (mimeograph).
38. There are many other legal aspects of new technologies (including the admission of computer-generated information as legal evidence), but we do not pursue them here.
39. For example, dropping water-tables in irrigated areas and the long-term consequences of excessive chemical fertilizers and pesticides used in conjunction with conventionally derived high-yielding seeds.