# Part I

# Introduction and Summary of Recommendations

## I. THE EMERGING TECHNOLOGIES

1. Technology has had a substantial role to play in creating the prosperity of the developed world. The continued enhancement of productivity resulting from changes in production methods has been translated into high and rising living standards. The impact of modern technology on developing countries could be far more profound in terms of the potential both for development and disruption.

2. The pace is quickening. The numbers employed in research and development (R & D) work, world-wide, have more than doubled in the last twenty-five years. Their inventions are now bearing fruit in a growing volume of commercial applications in such key technologies as microelectronics, biotechnology, new materials technology and new energy sources (which we shall refer to as emerging technologies). These technologies can be distinguished from other modern technologies by the speed at which their application is proceeding and by their wide scope, which far transcends narrow sectoral boundaries.

3. The most extensively analysed and discussed of the emerging technologies is *microelectronics*. The electronics industry, as such, is not new—radios were introduced in the 1890s, televisions in the 1930s. But what has revolutionised electronics is the advance in microprocessor and computer technology which is now generating a ten-fold increase in information processing capacity per unit of cost every five years. The implications of microelectronics and computers now extend far beyond the electronics industry itself, as they have converged with other emerging technologies to create a family of 'automation technologies'—computer-aided design (CAD), computer-aided manufacturing (CAM),

computer numerical control (CNC), industrial robots—and a whole range of applications which involve a merger of computer and communications technologies: 'informatics' and 'telematics'.[1] Automation and information technologies are beginning to transform not merely specific processes but the whole organisational structure of firms.

4. A second broad category of emerging technologies is *biotechnology*. In its widest sense, biotechnology has long contributed to agricultural development and to medicine. The 'green revolution' is a major recent application of more traditional biological knowledge. Modern biotechnology draws, like electronics, on a convergence of advances in several fields: molecular biology, biochemistry, microbiology and chemical engineering. It has a wide range of applications in the field of human and animal health, energy and food production, and industry. And it has revolutionary implications which lie both in the potential for creating new products and in the speed of development. It took an estimated ten years to develop cloning techniques for producing palm oil; it is now estimated that within four years it will be possible to make cocoa using similar methods.

5. *New materials technology* is leading to the replacement of some traditional materials, so intensifying a trend apparent since World War II. In that period, synthetic rubber production has grown from zero to more than double that of natural rubber; plastics from negligible amounts to levels which exceed, by weight, all non-ferrous metals combined; synthetic fibres from nothing to over a third of all textile fibres produced. Other new materials with versatility or exceptional properties based on ceramics or polymers will soon call into question the use of many traditional industrial new materials and create new opportunities for others.

6. New technology is, however, not necessarily 'high-tech'. So far we have stressed the importance of emerging technologies which are new in all societies. But technological advance also continues to take place as a result of the introduction or adaptation of more conventional technologies: the incremental improvements to existing processes and products and—of vital importance to developing countries—the use of technologies newly introduced, even if technically mature and commonly used elsewhere, especially in industrial countries. In the rural areas of developing countries, where the majority of humanity lives, new technology is introduced in various forms. There is continuous adaptation of traditional technologies—for example, improved ploughing, terracing and water control practices. There is change resulting from the use of conventional modern technologies such as chemical fertilizers, insecticides, high-yielding seeds and tractors. And, increasingly, the impact of emerging technologies will be felt, for example, from satellite

communications and modern biotechnology. In the industrial sectors there have been comparable developments and most basic industries using mature technologies have experienced advances during the last decade or so. One sector in which there has been particularly rapid technological advance is energy, where the increased price of oil has given a major stimulus to *renewable energy technologies*. Our Report endeavours to deal with the implications of new technology in this wider sense, while giving emphasis to specific emerging technologies.

## II. THE IMPACT OF NEW TECHNOLOGIES

7. In this Report, we review the evidence available on the economic and social impact of new technologies, with particular reference to their effects on economic growth, employment and international trade. The general analysis is illustrated with examples drawn mainly from half a dozen key activities: electronics, textiles and clothing, engineering, services, energy and agriculture. The essence of our analysis—in Part II Chapter 1—is summarised here.

8. Technological innovation has been a vital factor in fostering *economic growth*. Historical experience clearly suggests that technology, by raising the productivity of labour, capital, land and other natural resources, has had a dominant role in stimulating long-term growth. Developing countries have had less opportunity to benefit from industrial technology, but the increased agricultural (and overall) growth of many Asian countries, especially in the last two decades, is a measure of the actual, and potential, contribution of technological innovation. Looking specifically at the growth potential of emerging technologies, microelectronics has already made a major impact, at least in developed countries, in all activities involving a high degree of information processing, as in engineering where CAD has raised labour productivity by as much as twenty times in some specific operations. Biotechnology has begun to contribute to the growth of agriculture, where it can raise yields, improve varieties and extend the range of crops, and to the provision of more effective and lower cost medical and veterinary services. New materials technology is providing increased supplies of a more varied, technically effective and inexpensive range of industrial materials. Emerging technologies for producing renewable energy are reducing the costs of this resource and helping to remove bottlenecks in supply, especially in the rural areas of developing countries.

9. The emerging technologies are important, too, for *employment*. Most visible, and most studied, are the short-term, sector-specific, effects, especially of microelectonics as it has so far been applied in

developed countries. These are often negative in terms of numbers employed, as is apparent from the publicity given to those parts of industries, such as motor vehicle manufacture, printing, insurance and banking, where new microelectronics-based processes can readily substitute for more conventional and labour-intensive operations.

10. As against this are the longer-term, economy-wide and indirect repercussions, such as employment generated in activities supplying new or improved products or services (for example computers or computer software). These will provide much of the future growth in developed countries' employment, as is evident from a recent United States forecast that nearly all the twenty occupations with the highest growth in employment will be in information handling or technology equipment. Long-term historical experience of developed countries' economies suggests that growth through technological change can occur without creating overall technological unemployment. And today, the most technologically dynamic societies—particularly the United States and Japan—are among those least troubled by unemployment. The aggregate employment position clearly has a great deal to do with the economic conditions under which technology is introduced rather than with technology, *per se*. Economic expansion fostered by efficient economic policies and technological change could, moreover, make a positive contribution to employment; and this must remain an important objective of policy where unemployment and under-employment are significant.

11. In developing countries it is possible to see both negative and positive factors at work. Labour is being displaced by new technology in such activities as rice, sugar and tobacco harvesting where mechanical processes are being used, and by the development of new, competing, products. On the other hand, more labour is being employed bringing marginal lands under cultivation with improved foodgrain varieties and through increased yields and output brought about by improvements such as multiple cropping, high-yielding seeds, increased irrigation and fertilisation and the reduction of post-harvest losses.

12. It is not possible to estimate—and probably not very useful to speculate—what the net effects of emerging technologies are likely to be on employment levels in developed or developing countries. What can be said however with complete confidence is that there will be major structural changes involving the loss of existing jobs, with consequential costs to the individuals concerned and a need for measures to assist adjustment.

13. New technologies also influence the content and organisation of employment, and thus the requirements for specific *skills*. A major

concern in developed countries has been over technologically-induced 'deskilling', and the downgrading in status, work satisfaction, security and pay of particular groups of workers. The evidence has been mixed. The introduction of automated assembly in some developed country industries has replaced skilled by semi-skilled operators. Similarly in industries using microelectronics equipment, such as CNC tools, formerly highly-skilled steering and control tasks have been reduced, allowing semi-skilled operators to perform setting and programming tasks. However the broad thrust of new technologies is to create a large, generally unsatisfied, demand for highly skilled workers in particular areas such as computer programming, product development and equipment maintenance, as well as technologically-aware managers. Moreover, the main anxieties about new technology appear to be among the less skilled. In the services sector, low-skilled workers (often women) appear most vulnerable. Many routine clerical tasks appear likely to be eliminated by new technology in the office. While 'deskilling' represents a genuine anxiety for particular groups of workers, the connotations are not necessarily negative: loss of the traditional skill element in a job may not necesssarily imply a reduction in the job's intellectual content; and in developing countries new technologies may relieve skill constraints (though, on balance, the ability of these countries to take full advantage of new technologies depends on having a substantial cadre of technically-trained workers, which most of them lack). To summarise, new technologies will undoubtedly diminish both the skilled and unskilled aspects of many traditional jobs; but they will also create a demand for many new skills. Whether the affected workers gain or lose as a consequence depends how the technologies are applied, and in particular on the opportunities for retraining.

14. The *working environment* is affected in a wider sense, too. New technologies offer many opportunities to improve physical conditions of work—for example with the automation of dangerous processes in mining and manufacturing, or the use of microprocessors to monitor equipment still operated by workers—and to lessen the necessity for debilitating work and drudgery in many traditional occupations, especially in developing countries. At the same time there are health hazards associated with the way particular new technologies are used; examples include the fabrication of semi-conductor chips or the use of visual display units (VDUs) and work with toxic chemicals. In general, potentially higher productivity from the use of new technologies has allowed for greater flexibility in work organisation. Depending on how the technology is used, it can enrich the working life through a reduction in working time and greater possibilities for voluntary work-sharing and home-working; or else it can be applied negatively in ways that reduce the satisfaction and individual responsibility of workers.

15. The impact of new technologies on economic growth, employment and skills will be further modified through the medium of *international trade*. Trade helps spread the benefits of technology, both encapsulated in equipment and other goods and in the form of services. But it also creates some concerns. In many developing countries there has been worry on several counts: that process and product innovations will lead to previously labour-intensive and technologically 'mature' activities being relocated back to developed countries; that innovation in the new materials and biotechnology fields will reduce demand for their export products (especially raw materials); and that the growing cost of importing technology, with possibly shrinking opportunities to pay for it, may preclude its acquisition. The anxiety is heightened by the extreme foreign exchange constraint from which many developing countries now suffer, making them more than ever dependent on export earnings for growth. The evidence so far suggests that the increasing range of new products resulting from new technologies has created many niches which some of the more technologically advanced developing countries have been able to exploit, partly because of their flexible production structures. In other sectors, such as clothing, new technologies have not yet been widely applied, even in developed countries, because of rapid product innovation (in this case, constantly changing styles), short production runs, and a low level of industrial concentration. Automation has thus been deterred, and labour-intensive manufacturing in developing countries continues to have considerable potential—though to some extent frustrated by protectionism. On the other hand, in some cases, new technologies are undermining developing countries' competitiveness as developed country producers invest in automation, reducing the advantages of low labour costs. One danger is of growing polarisation, with the newly industrialising countries (NICs) able to participate in an expanding global trade in products incorporating high-technology processes, but with many of the low-income developing countries excluded from this trade, both by technological trends and trade barriers, including difficulties in acquiring new technologies. By this token, there is an even stronger reason for developed countries (and NICs) to remove protective barriers against products from the low-income developing countries.

16. Beyond the effects described above, new technologies will have a variety of complex and far-reaching *social* effects, which can only be sketched in the most simple, and speculative, way. Most societies are in a constant state of evolution in response to different stimuli, including technological change. The social structure needed to facilitate and support an 'information society' or an automated industrial society will be significantly different from that which exists today in most developed countries, let alone those in the Third World. 'Information technology' offers opportunities both for greater centralisation of decision-making

and control, and for greater decentralisation of economically productive and of leisure activities; together with developments in energy technologies, it could substantially reduce the attraction of urban societies. Biotechnology offers the opportunity to improve both nutrition and health-care, while some automation technologies and technologies to produce energy from renewable sources can help reduce environmental pollution. On the other hand, each of these emerging technologies can also be the cause of environmental hazards such as mutations resulting from genetic engineering and the production of toxic wastes. Another series of social issues, related to the use of information technology, concerns personal privacy and corporate or national security, including data protection. While the legal and ethical questions in this area may be complex, it is clear that even in the most technologically developed societies, public policy lags behind the progress of information technology, where this permits the easy and rapid flow of data between a variety of users and across national borders.

17. Advanced technology has also been used to create weapons of mass destruction. But this is a subject which would take us into ethical and moral issues of a completely different order, and is in any case outside the scope of our terms of reference. We do not therefore deal with it in this Report.

18. In considering all of these impacts it is clear that not only is there a substantial degree of uncertainty over what the eventual balance of benefits and costs will be, but there are also options at both a micro and a national level; these are the substance of technology policy.

## III. TECHNOLOGY POLICIES: THE APPROACH OF THE GROUP

### The need for strategies to harness new technologies

19. The speed and scale of technological advance has led to a great deal of apprehension about the impact of new technology. We do not believe, however, that it is possible for social groups, let alone whole societies, to avoid upheaval and uncertainty by avoiding new technologies. Although there are choices which can be made, the broad thrust of technological advance has a large measure of inevitability. Moreover, the extent of interdependence through trade, investment, telecommunications and travel is such that knowledge of new technologies is being spread everywhere.

20. In most applications, new technologies can confer positive benefits. As we have noted above, technological change is the main long-term

influence on economic growth. Developing countries have a particular need for high economic growth, given the extent of their unfulfilled needs. Technologies which can economise on scarce resources—especially of skills, capital and energy—will find many applications. In particular, they can be used to generate employment. Some of the applications of biotechnology have major potential uses in food production and medicine.

21. But these benign consequences cannot be automatically assumed and will not necessarily occur spontaneously. Not only are popular perceptions about the impact of new technologies often unfavourable, the reality can be, too. As we have seen, the immediate impact of microelectronics applications is often the displacement of labour from employment and traditional skills. The products of biotechnology and new materials technology may threaten specific raw materials supplying activities. Even if there are more than compensating gains in other sectors, the costs are real and may come to dominate public awareness of new technologies. Inevitably, too, those with the resources of know-how and wealth will make first use of new technologies, exploiting them to their own advantage and possibly the disadvantage of others. Some new technologies also threaten upheaval in delicately balanced environmental systems and patterns of social relations. Our Report will attempt to make a balanced appraisal of these issues to the extent that the evidence permits.

22. But where the assessment is broadly favourable, we shall argue that nothing is served by ignoring the negative consequences of new technologies or by taking refuge in the comforting belief that societies will painlessly adapt to change. There are real fears and a principal objective of public policy should be to mitigate them. It can do this by raising awareness of the changes which technology is bringing about and to identify those areas in which there are options, and where choices have to be made.

23. A prime need is for governments, individually or collectively, to develop a capacity for analysing—that is, forecasting, assessing and monitoring—the impact of new technologies. By this, we do not mean that government should ignore the inherent uncertainties in technology and in markets. But it is possible, on the strength of experience so far, to forecast the types of industries and services within which, for example, microprocessor-based systems will become common; some of the categories of skilled manpower which will be in excess demand or excess supply; some of the commodities which will increasingly be replaced by new materials. The exercise can be carried out with varying degrees of sophistication depending on the skills and resources available to particular governments.

24. On the basis of technology forecasts and assessments it should be possible for individual governments, in consultation with other interested parties (including trade unions), to formulate a positive response to new technologies rather than to react *ad hoc* and belatedly. The substance of a strategy to make best use of new technologies is discussed in detail later. Many of the policy options are specific to particular countries, or types of countries, but there are some common elements. In essence, what is involved is extracting from the process of evaluation some clear priorities: activities in which the greatest benefits from new technology will accrue; others in which adjustment costs are unavoidable and likely to be particularly severe. It is then possible to plan for future education and training needs. And it is possible to devise a creative approach to adjustment which is concerned not just to minimise the inevitable difficulties involved in a process of rapid economic and social change, but to encourage employment generating opportunities.

**A 'systems' approach to new technologies**

25. The emerging technologies which are the principal focus of our Report have led not only to new plant and equipment—or 'hardware'—but to new systems, or methods of organisation. To explain this distinction in historical terms, the development of the textile history, for example, in the 18th and 19th century industrial revolution was attributable both to 'hardware' changes (mechanised looms and spinning machines) and to the system of factory organisation. More recently, development of the vehicles industry was based initially on an innovation in 'hardware'—the internal combustion engine—but subsequently on advances in the system of production—the assembly line. In the United States this has brought with it a panoply of associated infrastructure and ancillary industries and a whole new system based on the automotive society.

26. Present day emerging technologies also have to be seen in terms of the wider 'systems' implications. The most important applications of microelectronics are occurring where systems can be devised to utilise the properties of new technologies—miniaturisation, increased flexibility and precision—more effectively: the combination of micro- and mini-computers with office machinery to produce new office systems; the use of sophisticated process control systems and the integration of automation technologies, such as CAD and CAM, into new systems of factory organisation; the adaptation of systems of personal transportation, distribution and financial services to reflect the possibilities of households carrying out an increasing range of tasks through computer and video equipment at home. Such are the vast organisational implications of applying microelectronics that systems design and development can increasingly be seen as a new technology in itself, within

which advances are made in optimising the component elements of a system operating in combination rather than independently.

27. Systems development, in a broad sense, is also crucial to the future applications of biotechnology. Thus, in medicine, biotechnology is leading not only to improved therapeutic and preventive products but to new diagnostic agents which, to be used effectively, require quite radical changes in the system of medical organisation. Similarly, the enormous potential of biotechnology in improving the productive potential of both crops and animal husbandry is only likely to be realised where it is employed in a system which furnishes appropriate economic incentives and support services.

28. We believe that the adoption of a 'systems' approach to emerging technologies—by governments as much as by enterprises—is essential and that serious errors or inadequacies in policy will result from a failure to do so. The adoption of new technologies depends not only on the existence of a capacity to operate equipment but on a capacity to devise organisational systems which are appropriate to local conditions. Developing countries, in particular, are littered with expensive imported equipment (and, increasingly, domestically produced items) which embodies new technology but is unproductive because of lack of a 'systems' capability to make effective use of it; this is especially the case in relation to computers. While countries vary greatly in their ability to produce the equipment associated with emerging technologies, all countries can, and should, develop some 'systems' capability for employing new technologies productively. Societies which are deficient in this area will be retarded in employing new technologies, and equipment will be inefficiently used.

**Technology for people**

29. A combination of technological and economic factors determines which new technologies are developed and introduced, where, when and for whom. For the most part, the governments and large companies of major developed countries provide the 'push' for developing new technologies; the consumers in these societies, and government departments, including the military, the 'pull'. But a broader conception of social need has to take into account the implications of new technologies for people who have little purchasing power and who live in countries with small indigenous technological capacity. Most of the world's population—75 per cent—lives in poor countries. But most of the world's R & D—95 per cent—takes place in rich countries, and an even higher proportion for emerging technologies.

30. The disproportion of R & D between developed and developing countries is not merely inequitable; it contains dangers. For while

R & D in rich countries has often been of benefit to poor countries, this is not always the case. One danger is that technologies which originate in developed economies are likely to incorporate a labour-saving bias which can be inimical to countries with an abundance of surplus labour and a relative deficiency of savings and investment. This is of particular concern now, given the labour-saving potential of many applications of microprocessors and other new technologies. Another danger is that, because most innovations are based on the markets of relatively rich countries, most new products will reflect the tastes of relatively high-income consumers, neglecting others. A third element is that, for technical reasons, there are some areas of technology which are locale specific and where R & D has to be done *in situ*. One illustration of great relevance to developing countries is crop production.

31. The use of new technologies can contribute indirectly to meeting the basic needs[2] of poor people to the extent that they raise the wealth-creating capacity of their societies. There are also ways in which governments and other decision-makers can create a more specific connection between these needs and the potential of new technologies, and so offset the biases described above. One is to assist in the development of products and services which are specifically geared to meeting the needs of poor countries and low-income groups, such as low-cost construction, water supply and sewage disposal techniques; preventive tropical medicine; improved low-cost transportation (bullock carts, cycle-rickshaws); low-cost renewable energy, especially for rural households; drought- and pest-resistent and high-yielding agricultural crops, especially of food indigenous to developing countries. The other is to create conditions in which traditional technologies, especially those which are labour using, can be enhanced or reconciled with emerging technologies. One approach is to 'blend' these two types of technology. This can occur, for example, with the use of remote sensing through satellites to survey water resources for peasant farming communities; the use of information technology to improve the delivery of low-cost health and education services; and the adoption of microprocessor control devices to improve quality and reduce waste in cottage textile industries or food processing. The distinction between the social goals and priorities of developed and developing countries, however, is not rigid. The citizens of the former no less than of the latter are concerned about relating technologies to socially useful ends, and in particular about the high proportion of technological endeavour devoted to military applications.

32. The concept of 'technology for people' has another application. There are casualties from technological change, even that which benefits the majority in a society. Mechanisms then become necessary to facilitate retraining and relocation so as to achieve adjustment which is not

only smooth and efficient in an economic sense but is linked to assistance for vulnerable regions and social groups (for example low-income groups, youth or older workers, women). Moreover, it is desirable that, where possible, new technology is introduced after genuine and full consultation with those affected by it and that emphasis is given to many innovations which improve, rather than diminish, the quality of employment. In developing countries, 'adjustment' problems are largely centred on those in 'organised' labour—in offices, plantations or factories. However the majority of the population, and especially the poorest, are not so 'organised' but earn a living from self-employment in subsistence or smallholder cash-crop farming or in the 'informal' sector. In that context, the question is less one of 'adjustment' than of whether new technology, combined with the accumulation of capital, can create employment and other opportunities to raise the standard of life.

**A differentiated approach**

33. While we focus on the distinct issues involved in the management of technological change as between developed and developing countries, clearly there is need for greater recognition of a more differentiated approach. There is an enormous range of technological capacities and needs between countries because of differences in size, living standards, availability of scientific and trained manpower, and resources endowments. Within the Commonwealth, 27 out of 49 countries each have a population of under one million; yet India alone is estimated to have almost three million scientists and technologists. Britain has a GNP over 1,000 times the size of the ten smallest Commonwealth countries' economies combined—and an even greater dominance in R & D expenditure—despite itself falling well behind the United States and Japan in this respect.

34. A categorisation of countries is attempted in Part II Chapter 2, but a few important distinctions can usefully be made here. Among industrial countries there is a distinction between those major countries which are themselves heavily involved in the development of emerging technologies and others, smaller countries, which are concerned with adaptation to changes originating elsewhere. For large low-income countries such as India or China there is a substantial technological capacity which can be deployed in the indigenous development of a wide range of technologies: basic science as well as technology applications; production as well as adaptation of new technologies, both conventional and emerging. For small states, options are considerably more circumscribed: by the diseconomies of small scale; the limited variety of human and material resources available in relation to the demands of technological development. A much higher proportion of technology has to be imported and the exercise of policy is largely in terms of import selection and adaptation.

35. The question of technological choice is also relevant to the current crisis of hunger and economic deprivation in the countries of sub-Saharan Africa. Although the crisis is complex in origin and has various causes—including changes in climate, socio-economic structures and national and international policies—it has created its own technological imperatives. These are to adapt improved food-growing techniques rapidly to local conditions and to create a capacity to operate existing industries and infrastructural services efficiently. The crisis has also diminished the resources available in most of these countries to carry out technological development, without external assistance.

36. There are other factors, too, which influence technology policies. Societies have different goals; for example different weights are given to economic growth, environmental protection and self-reliance. Clearly, it would be excessively rigid to apply the same specific set of policies in countries with such widely different goals and characteristics. Not only country characteristics but also different technologies will make distinct demands. For example, in the agricultural field the development of a technological capacity in a developing country will involve fundamental scientific work in the country of application, say in the comprehensive analysis of local plant or animal life. But much industrial technology will be imported, and the development of an indigenous capacity might as well be restricted in most cases to the ability to carry out adaptations.

## IV. SUMMARY OF POLICY RECOMMENDATIONS

### Essential tasks for government

37. We have stressed the great power and speed of technological change, especially that originating from the emerging technologies. The inevitability of technological change does not however mean that societies, and specifically governments, need to adopt a passive or deterministic attitude towards it. There are options in terms of the speed and direction of technological change; policy choices to be made; socially beneficial technologies which can be actively promoted; technologies with negative impacts which can be discouraged or adapted. In order for each country to be able to make choices and take maximum advantage of new technologies, governments need to be quite clear as to the goals they are pursuing. As we have seen above, these differ between countries and over time, and are multifaceted. Economic growth is likely to loom large among them but we have considered also the relationship of technology to employment objectives and to the fulfilment of the 'basic needs' of low-income groups. To translate these social goals into effective policy requires the development of a

technological capacity: trained and educated scientists, technologists and technicians; a capacity to carry out and utilise R & D; a capacity to adapt, if not to produce, technologies indigenously; a government decision-making apparatus which is well informed about technology matters, and able to respond quickly where governments are called upon to act. Different societies will vary enormously in the technological capacity they can realise because of differences of size, income level and stage of development; but even the smallest and poorest countries need some capacity to make choices and to adapt technology to local conditions, especially in their agricultural sectors.

38. In sketching some essential tasks for government, we are fully aware that many of the problems of managing new technology are at a 'micro' level. These will be resolved on a decentralised basis by individual firms and workers' representatives, and through transactions between buyers and sellers of goods and services. Furthermore, in almost all countries of the Commonwealth there is recognition that private entrepreneurs are crucial agents in technological innovation. In most developing countries the principal source of such entrepreneurship will be small-scale private farmers and among businesspeople and artisans in the 'informal' sector or small-scale industry. It is the domestic entrepreneurs who require new technologies who can most effectively disseminate them, assimilate them and adapt them to local conditions. The role of government in this connection is primarily one of creating a general framework of economic policy conducive to investment and risk-taking, and in particular to ensure that there are adequate incentives for small farmers and businesspeople and sufficient access to venture capital to finance innovation.

39. While such technological innovation will occur through the market mechanism, this in no sense diminishes the necessity for government to play a key role. The limitations of markets, and the implications of new technologies for so many aspects of life, are such that governments cannot opt out of the management of technological change. In most developing countries, where indigenous entrepreneurs are usually small and infrastructure generally under-developed, this role is likely to be relatively more important. There are certain areas where, it is generally recognised, the market mechanism does not function effectively and where governments of countries at all stages of development have crucial tasks to perform. In relation to technology these areas include:

**technological capacity*. The development of an indigenous technological capacity is important not for its own sake but to enable society to make effective use of new technologies or to adapt them to local circumstances. Private firms and individuals can make a major contribution, but there may be reasons of scale, short-time

horizons, difficulty in capturing an adequate proportion of the gains, or high perceived risk, why they under-invest. Private finance is especially likely to be deficient for technological development in farming, particularly small-scale farming. In most developing countries the predominance of small farms and the large relative size of the agricultural sector mean that much of the responsibility for creating and fostering indigenous technological capacity in this area falls upon governments. Even in developed countries much responsibility in the agricultural sector falls upon governments because of the difficulty of the private sector in capturing compensating gains from some kinds of agricultural R & D. More generally, private finance will not provide adequately for basic scientific research. It will also be deficient for the earlier stages of technology development, before commercial application is in prospect—as with, for example, plant breeding and renewable energy sources such as windmills;

* *education*. The availability of an adequately educated and trained workforce is an essential prerequisite for using, adapting and managing new technologies. Governments have the principal responsibility for providing this education and, if not for promoting vocational training directly, then for setting standards;

* *social costs*. The use of new technology may create some social costs—including environmental damage and the invasion of privacy—which call initially for assessment in the public interest and then for legislative or other controls. There are also private and social costs to workers, businesspeople and communities resulting from adjustment. Adjustment need not be seen as a passive and reluctant response to change. Through planning, consultation, education and retraining it can be approached positively;

* *public goods*. Technological innovations will not proceed without active government support in those areas of collective need, such as health, water supply and transport systems, for which governments have pre-eminent responsibility. Moreover, government departments—administration, defence, telecommunications—can be among the principal users of new technology;

* *basic needs*. An important area of market failure is R & D into items such as preventive medicine, low-cost housing, and nutrition, which are of benefit to low-income groups. Private firms have little interest in providing goods or services where market returns are not likely to be significant; and

* *information*. Properly functioning markets require widely accessible information. But in the field of advanced technology this is difficult to obtain, especially in developing countries and among scattered small farmers and businesspeople. There are property

restrictions, such as patents, imposed by manufacturers (including transnational corporations) and considerable costs in acquiring information. Governments can improve the situation in many ways. They can, for example, encourage diffusion through extension and information services, and economic incentives such as subsidies to promote the use of improved methods of production.

**Decision-making machinery and technology**

40. We believe technology policy is a crucially important part of government decision-making in all countries. Both for this reason and because technologies are not always sector- or product-specific, a focal point in government for coordination and decision-making should be established at a high level, transcending departmental or functional divisions. In order for it to function effectively, an ability to keep up-to-date with technological developments and to predict and assess their economic and social impact is crucial. This involves governments establishing an effective capacity to undertake:

—*technology forecasting*, necessarily approximate and at a broad perspective level, but an essential management tool for indicative planning purposes. It could be used, for example, to give early warning indicators of, say, future threats to exports from substitutes and long-term employment bottlenecks;

—*technology evaluation*, an important stage in making major decisions regarding new technologies. It could involve conventional accounting and economic assessment supplemented by an evaluation of social and environmental effects and the wider 'systems' implications; and

—*technology monitoring*, to keep the effects of a new technology under review once it has been installed.

41. We recognise that the creation of even a minimal administrative framework for technology entails costs and, given the shortages of skilled labour, involves difficult choices. We also recognise that the technological and administrative capacity of most developing countries, especially low-income and small states, is likely to be small. Much could, however, be achieved on a limited scale. Even more could be done through international collaboration, and with external assistance. We shall focus specifically on the international dimension of technology management, with particular reference to the Commonwealth's role.

42. Within this framework, we shall set out some general recommendations, but bearing in mind that the needs and resources of states are very different. We shall try to highlight recommendations which have

specific relevance for developing countries, and particularly for low-income and small states without a substantial technological capacity.

**Creation of an indigenous capacity**

43. A necessary prerequisite for societies to develop and adapt technologies appropriate to local conditions is the creation of an indigenous technological capacity. Even societies which must rely largely on adaptation require such a capacity.

44. A critical area of policy is *education and training*. In addition to education and training measures designed specifically to facilitate adjustment (see paragraph 54), this requires:

—giving enhanced importance to scientific and mathematical education in schools and to familiarisation with computers;

—making effective use of new information technologies to supplement teaching and training methods, in combating illiteracy and in developing modules of specific vocational training;

—increasing the overall supply of some new specialised skills, such as those possessed by systems designers, electronic repair and maintenance personnel and programmers;

—providing general and specific training for government and other decision-makers in relation to new technologies;

—orienting education and training to develop entrepreneurial skills;

—supporting technology awareness programmes at the workplace, particularly through trade union education;

—increasing technological awareness among those outside the formal economy in developing countries, especially small farmers, through demonstration and extension work and by specific training required to increase the effectiveness of technology 'blending'; and

—taking steps to ensure that incentives are available to retain an expensively educated and trained scientific and technological workforce within the scientific community of their country of origin.

45. *Support for indigenous R & D* is particularly necessary in developing countries to deal with their unique problems. For those countries which have developed an R & D capacity, there are some obvious priority areas, which should be adapted to the characteristics of the countries concerned:

—R & D on products, services and delivery systems of special interest to the poor, where purely commercial R & D is likely to be inadequate because of insufficient market returns;

—modernisation of traditional technologies to increase output in a way which maintains their employment generating potential; and

—R & D on 'blends' of advanced technologies with traditional technologies.

46. High priority needs to be given, especially in developing countries, to ensuring that the *scarce resources* of skilled workers and finance *are efficiently used*. This is especially true of R & D resources, and in this connection we would suggest:

—establishing priorities for government or government-supported R & D programmes, on the basis of felt needs;

—ensuring a more appropriate balance between development and basic research activities, and again to relate both to felt needs;

—raising the proportion of contract research;

—undertaking regular and rigorous external evaluations of programmes and institutions;

—making collaborative arrangements among neighbouring countries, especially small states, to achieve greater economies of scale and to respond to common needs and problems;

—encouraging inhouse work in private companies by means of selective tax incentives; and

—financing R & D by a levy or cess on production to ensure that beneficiaries seek value for money and to provide increased resources from enterprises which benefit from public R & D.

47. A fundamental problem in many countries, especially developing countries, is the weak linkage between invention and innovation. Governments can do a great deal *directly to promote technological diffusion* among small firms and farmers by ensuring that supporting services and delivery systems for new technologies are available (for example credit and fertilisers to be used in conjunction with improved seeds). Private sector activity can also be catalysed by the provision of:

—centralised engineering design and consultancy services for establishing and operating plants, assessing technologies, and undertaking project studies, management and training;

—advisory extension services for agriculture and manufacturing where these are deficient;

—centres for the common use of new technology (e.g. computers and programming services);

—repair and maintenance services;

—centres for testing and quality control; and

—telecommunications and other infrastructure.

To avoid inefficiency, publicly established institutions could be made to sell, lease or hire out their services, and to operate on a profit-sharing principle, with frequent private sector staff secondments and appointments to Boards of management.

48. A suitable climate for technological innovation depends on a favourable conjunction of *economic and social policies and other measures favouring risk taking*. Among the more important factors are the availability of:

—*venture capital* for entrepreneurs and insurance facilities for high-risk ventures (such as crop production in certain areas);

—*tax incentives* which encourage risk taking and investment without inducing a labour-saving bias;

—*subsidies* to encourage adoption of improved methods, such as optimum fertilisation;

—*commitments* to cushion scientific and technological work of long-term importance from the effects of short-term economic fluctuations and emergency measures consequent upon adverse economic shocks (as currently in sub-Saharan Africa);

—efficient market mechanisms utilising *price incentives* to encourage innovation in such fields as agriculture and energy and to avoid 'inappropriate' technology being introduced by distortions in labour and foreign exchange markets; and

—*competition, patents and trademarks policies* which strike an efficient balance between protecting innovations and avoiding monopoly. Particular care is necessary to ensure that patents and trademarks are not used in developing countries by multinational companies to inhibit the diffusion of technology.

49. Governments have a direct responsibility *as important consumers* of the products of new technology. They need to:

—develop indigenous technology while avoiding costly protection. Appropriate preference margins for local suppliers, declining over time, are better than the exclusion of imports;

—stimulate innovation in local firms. Component and equipment performance requirements can be used;

—make comprehensive and systematic assessments of the technology options on major contracts. These should incorporate not only cost benefit considerations but the wider impacts of technological change; and

—ensure that large orders for goods and services purchased under aid programmes are subject to the same assessment discipline as other contracts. *Aid donors* should collaborate with local governments in taking appropriate measures to achieve this.

**Technologies for basic needs**

50. A major aspect of technology management is concerned with *harnessing the potential of new technologies to social needs*. This may not happen spontaneously since, first, commercially oriented technology will not normally be directed adequately to the basic needs of the mass of poor people in developing countries, and secondly, there are externalities (wider social effects) which conventional economic assessments will not capture.

51. The lack of provision of technology *for basic needs*[2] can in part be rectified by developing countries' governments. They need to:

—support R & D and the diffusion of innovations so as to develop products and services of particular benefit to low-income groups. Examples would include improved strains of indigenous foodstuffs, low-cost energy sources, preventive health measures, new medicines, low-cost construction, water supply and transportation techniques; and

—use new information technologies to develop more efficient delivery systems for decentralized health and education (e.g. mass literacy services).

52. *An effective process of independent technology assessment is required to monitor the wider social impacts of technology*. Among particular areas of concern are:

—*environmental* hazards, though some of these can be mitigated by the development of new technologies (for example to dispose of toxic wastes, substitute renewable for non-renewable resources) and others by the enactment of effective controls (for example on activities causing acid rain);

—*health and safety*, which necessitates more investigations into burgeoning new biotechnologies, effective legislation for consumer and worker protection, with active support from the workforce in monitoring and control; and independent inspectorates to enforce legislation; and

—access to information and protection of *privacy and security* consequent upon improved information technology, which may necessitate additional legislation to safeguard the rights of individuals (including employees) and of corporate entities (including governments).

**Adjustment policies**

53. *Positive adjustment policies* are necessary to minimise adjustment costs in relation to the benefits from technological change and to compensate for the unevenly distributed costs of new technologies. They would thus help to reduce resistance to these technologies. Adjustment policies cannot be separated from questions concerning the *general conduct of economic policy*, since the evidence suggests that adjustment will be smoothest when, among other things:

—*macro-economic* policy leads to low unemployment, rising living standards, price stability, a steady expansion of demand and external equilibrium; and

—*micro-economic* policy makes judicious use of appropriate market incentives and resources.

54. *Effective employment policies* are most important for efficient adjustment. Clearly, the resources available will vary from country to country, but in developed countries the following are of proven value:

—*school education* which, through mathematics and scientific understanding, lays the foundation for future vocational training and all-round flexibility;

—*continuing education*, as a concept, to raise scientific and technical capabilities throughout the working life;

—*retraining* programmes for those displaced, as part of an integrated approach to adjustment assistance including counselling and resettlement assistance;

—*specially targeted employment and retraining programmes* for vulnerable groups particularly at risk from technologically-induced unemployment (such as youth, women, the handicapped);

—*redundancy* compensation which is generous but linked where possible to re-employment; and

—*portability of housing and pension entitlements* to encourage mobility.

55. *Specific regional policies* can provide an additional element of support for adjustment given that technological unemployment is

usually unevenly distributed. The *provision of infrastructure* and differentiated *fiscal incentives* should be important components of regional policy.

56. New technologies will only be welcomed by those directly affected as workers if action is taken to ensure early and thorough *consultation at the workplace*, and in particular to ease anxieties in respect of health and safety, work satisfaction and 'deskilling', as well as job security. Various specific steps can be taken to safeguard workers' interests:

—recognition of the *right to unionise;*

—application of *international labour standards*, especially in relation to health and safety and collective bargaining; and

—adoption of *technology agreements* between workers' organisations and management.

57. Whilst many of the above measures arise largely from the experience of adjustment in developed countries, some are also of relevance to the developing countries. In addition developing countries have their own particular anxieties about the negative impacts of technology and, albeit within much greater financial constraints, recognise the need for *adjustment measures related to developing country conditions*. There needs to be:

—support for R & D, training and diffusion in respect of *technology blending*, as one means of preventing disruption (or providing enhancement) of traditional labour-intensive technologies, for example the use of microelectronics quality controls in traditional craft industries;

—*promotion of diversification of traditional primary products* to counter the consequences of the displacement of demand for specific products (such as sugar and some natural fibres). Diversification programmes could be supplemented by financial support for R & D into new products and processes based on existing raw materials as well as into suitable alternative raw materials; and

—support for producers of labour-intensive *manufactured exports* faced with additional competition from firms in developed countries using new labour-saving processes. For exporters in the NICs, adjustment may be possible within these industries, through upgrading and adopting more capital-intensive techniques. Those in low-income countries would need to seek out new opportunities for producing labour-intensive goods and services. Overall pessimism is, however, unjustified from a technological standpoint, and it remains important for developing countries to pursue *exchange*

*rate and trade policies* consistent with rapid export growth of non-traditional exports. In this respect there is need for urgent and far-reaching action to remove barriers to trade, on the part of both developed and developing countries.

**Importing technologies**

58. For reasons we set out earlier, a major priority in technology policy is to develop a capacity for *choosing, using and adapting imported technologies*. This capacity is *especially important for small states*. It can be enhanced through:

—government assistance (organised on a national or regional basis) for private firms in searching for external new technologies. Such investigations may be through national registries, technology data banks, information and documentation centres, specialised libraries and the use of diplomatic and trade representatives;

—vetting major technology equipment imports. This is necessary to ensure the effective transfer of technology through 'unpackaging' or the provision of associated training and servicing (i.e. the 'software'), and to evaluate the demands which will be made on public administration (i.e. the 'systems' implications);

—making effective use of all the means of obtaining new technologies—through licensing, joint ventures and foreign investment. However, some vetting is likely to be necessary, since transfer will not be automatic; and

—acquiring the 'software' component of new technologies (the 'know-how' and 'know-why') directly through consultants, management and service contracts, overseas training and various forms of technical assistance. These sources will not, however, lead to technology transfer unless this is actively pursued through performance requirements and through the development of a local capacity to absorb the new technologies.

**International cooperation**

59. While there is much which can be done at the national level in managing technological change, it is clear that all countries, and particularly developing countries, have a lot to gain by *international cooperation* in this area. In some cases assistance is required by the poorer and smaller countries from those which are technologically more advanced, while in others there is scope for cooperation on an equal basis. In all cases the focal point we recommend (paragraph 40) be established in government, should coordinate the measures of cooperation.

60. *Assistance with education and training* is essential for most developing countries to strengthen domestic capacity, in order to meet

the needs described in paragraphs 44 and 54 above. The requirement is all the more urgent in the poorer countries where resources for education are severely constrained. Financial and technical support is needed particularly in:

—the provision of education hardware and software for use in schools;

—the establishment of training institutes; and

—the provision of scholarships for training.

61. Much of the responsibility for technical assistance, including training, falls on multilateral and bilateral technical assistance programmes; but multinational companies can make a contribution through the establishment of specialised training units and R & D facilities in host countries to develop the skills and research needed for their local activities, and in joint ventures with local companies (including those in the public sector).

62. A case could be presented for establishing one or more international institutes for undertaking both R & D and training in selected areas of new technology to help overcome issues of common concern. One example might be the use of remote sensing techniques for predicting rainfall or water resources or long-term changes in climate, and increasing knowledge of the reasons for such changes.

63. *Regional cooperation* may be more appropriate for countries too small to justify their own technical training institutes, even if international assistance is available to them. In this case:

—employment programmes should be drawn up jointly with other developing countries on a regional or sub-regional basis; and

—regional training institutes should be strengthened or established where they do not already exist.

64. *Exchanges of personnel* are also called for, both between developed and developing countries and among developing countries, so that skills in and experience of new technologies can be shared. Such exchanges may take the form of:

—traditional technical assistance, whereby skilled workers from technologically more advanced countries (developed or developing) help to train workers in less advanced ones; and

—workers, managers or policy-makers from less advanced countries gaining technical skills and experience by working in more advanced countries—but in this case complementary measures may be needed

to persuade most of the newly trained personnel to return to their country of origin.

65. *Joint R & D efforts* are essential, given the existence of substantial economies of scale and common needs and problems. This applies both to the development of new technologies (particularly various biotechnologies and new energy sources, for which close contact with local conditions is often necessary) and to the adaptation of technologies which have been transferred from other countries. Amongst the priority areas are:

—improved coordination of R & D in developing countries on a regional basis—particularly among small states—to minimise duplication of effort and increase exchange of findings;

—increased allocation of resources in developed countries to develop new technologies directed at meeting the needs of developing countries; and to support R & D institutes in developing countries;

—improved dissemination of R & D results internationally. Consideration may be given to the development by the United Nations of an easily accessible data base, with information on R & D in new technologies being carried out by all United Nations bodies if not more widely; and

—assistance with the establishment in developing countries of compatible technology information systems.

66. Cooperation in *technology policy formulation* may also be beneficial to developing countries, both in terms of needs identification and in drawing up appropriate policy responses. Some advice is already given at an international level but it could be increased and better coordinated, while exchanges of experience have yet to occur on an extended basis. We attach particular importance to enabling developing countries to increase cooperation among themselves. Action is required at several levels:

—extending UN bodies' capacity to offer advice on technology policy while increasing efforts to reduce overlap and inconsistencies;

—strengthening the role of other multilateral bodies, such as the World Bank, in technology policy formulation, both in their general approach to policy conditionality and dialogue and in the conditions surrounding the supply of equipment and systems development;

—developing institutional mechanisms for exchanges of technology policy-makers' experience; and

—harmonising technology policies (and technical standards) where joint R & D or industrial development is an objective.

67. There are a whole series of *other international issues*, currently being discussed in international fora, which have a direct bearing on technology management at a national level. They centre on the terms and conditions of technology transfer or the interaction between technological change and international trade. The issues include:

—the terms of 'codes of conduct' governing foreign investment, transfer of technology, restrictive business practices, and activities of transnational corporations;

—protectionism, especially 'technological' protectionism;

—transborder data flows;

—commodity stabilisation and diversification programmes as envisaged under the UNCTAD Common Fund; and

—the United Nations Convention on the Law of the Sea, as related to deep-sea mining.

**Commonwealth cooperation**

68. Having analysed some of the policies needed for the management of technological change, and recommended ways in which the international community could enhance its cooperation to help implement them, we addressed the question of how the Commonwealth could assist, and what role it could play through the Commonwealth Secretariat.[3] We were aware of the funding constraints involved in suggesting any new activities, and of the fact that, to be realistic, any recommendation to that effect must be modest in scope. We were also conscious of the need to avoid duplication of existing activities and of the very different requirements of Commonwealth countries as regards technology.

69. But we do see an important role for the Commonwealth Secretariat in undertaking certain information and promotion activities and advisory services, as well as in organising training courses and seminars on the management of technological change. We have made recommendations on each of these, though it should be understood that at this stage these are of an indicative nature and are for illustrative purposes only. More detailed assessment, including costing, would need to be carried out on their implications before a fully informed decision could be made. Those activities which are agreed, should be undertaken by the Secretariat in close consultation with the focal point in government which we have recommended above (paragraph 40).

70. *Information and promotion activities* are needed to help Commonwealth developing countries in particular to keep abreast of the large number of developments occurring in the technological field. At the

same time more information is needed on the impact of new technologies, especially in developing member countries. As a beginning we recommend the Commonwealth Secretariat should:

—encourage and, where requested, assist Commonwealth countries to organise the regular collection and dissemination of information, in an accessible form, on new technologies and on their economic and social impact, drawing on countries' own experiences in particular and on the work of the United Nations and other international agencies;

—compile and distribute to member governments a quarterly newsletter aimed at policy-makers, covering technical and socio-economic aspects of new technologies in a summary form, with source references for those interested in further details;

—undertake comparative studies of the impact in different environments of new technologies;

—raise the level of public knowledge of its activities in the technology field and their potential usefulness to member governments and non-government bodies; and

—promote greater discussion of key technology policy issues at meetings of Commonwealth Ministers and Officials.

71. In addition the *advisory services* of the Commonwealth Secretariat (and of the Commonwealth Science Council and several Commonwealth non-governmental organisations) should be enabled to provide greater assistance to member governments with technological assessment and forecasting. They will therefore need to be expanded:

—to enlarge their focus on the use of new technologies and the possibilities of blending them with traditional technologies;

—to provide special advice, in particular to African member countries, on how new technologies (e.g. biotechnology) might be used to meet countries' urgent needs, especially in relation to food supply; and

—to establish a panel of experts who would be available to advise member countries on technology matters.

72. A valuable contribution could be made by the initiation of a *training and exchange programme*, with the aim of improving knowledge of new technologies and of their impact. This should include:

—organising the training or exchange of key personnel (decision-makers and operators) concerned with the choice and application of new technologies as a priority under the Commonwealth Industrial

Training and Experience Programme (CITEP)—an idea which received support from Employment and Labour Ministers at their meeting in June 1985; and

—arranging seminars for key personnel to exchange views on, and experiences with, new technologies.

In both cases co-financing from a variety of sources, including the private sector and other international bodies, needs to be considered.

73. Looking further ahead, and on a more ambitious scale, the Commonwealth could be the focus of an attempt to extend the use of advanced communications—through satellites—for educational purposes, particularly for specialised and costly higher education. The Commonwealth as a whole, or regional Commonwealth organisations, can usefully provide a focus for multinational efforts in this field which could be facilitated by the common use of English. Small states in particular may benefit from such arrangements since they are finding traditional systems of higher education costly.

## NOTES

1. Definitions of these and other technical terms are contained in a glossary (Appendix 1).
2. See glossary (Appendix 1).
3. And, where appropriate, through the Commonwealth Science Council.