TECHNOLOGICAL CHANGE

Enhancing the Benefits

VOLUME I

Report by a Commonwealth Working Group

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Commonwealth Secretariat

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Report of a Commonwealth Working Group

Volume I

Commonwealth Secretariat, Marlborough House
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Foreword by the Commonwealth Secretary-General

Technological change arouses strong and conflicting emotions. There is apprehension that new technologies will be economically and socially disruptive but also hope that their vast productive potential can be harnessed to raise living standards and eliminate poverty. There are fears that the power and speed of technological change in communications are fast eroding national sovereignty but there is awareness of the opportunities which are presented by closer interdependence between nations. There is a sense of injustice aroused by the overwhelming concentration of technological R & D in countries which are already rich but also a sense of pride in the technological advances which are being made in many developing countries despite major resource constraints.

The subject is as difficult and complex as it is important. The mandate from Commonwealth Heads of Government, acting on the recommendation of Employment and Labour Ministers, that the Commonwealth Secretariat should constitute a Working Group to examine the management of technological change was, therefore, a particularly challenging one. I was fortunate to be able to assemble a very distinguished group of men and women who were able to bring to bear on the problem their very considerable experience derived from government service, business enterprises, trade union work and academic analysis, in a cross section of Commonwealth countries. The Group's Chairman, Professor Menon, is a noted physicist, and in his capacity as Chief Scientific Adviser to the Government of India and member of its Planning Commission he is at the centre of his country's vigorous programme utilising emerging technologies for development. I am grateful to them all.

While the details of the subject under study are highly technical, the essentials are not, and they touch on some of the central issues confronting policy-makers. For example, a major theme of the international community during recent years, and one which has been

reflected in Commonwealth Secretariat reports and activities, has been the need for governments to recognise the reality of growing international interdependence and to advance multilateral cooperation accordingly. The development of technology is constantly widening and deepening interdependence. Satellites, multinational computer systems and 'telematics' are creating opportunities for rapid international communications between individual companies and governments. As public—though not government—responses to the African famine have recently shown, the concept of a 'global village' is no longer in the realm of futurology. The rapid international transmission of data is making traditional tools of national economic management obsolete. It has facilitated instant movement of massive amounts of capital which can now overwhelm governments of even the most powerful countries unless they are willing to harmonise their policies with those of others. The expansion of robotics into manufacturing and the advance of new materials technology and biotechnology are transforming patterns of trade and specialisation worldwide; yet existing multilateral arrangements to ease the inevitable frictions and encourage international adjustment are inadequate for their growing tasks.

Unemployment is a problem almost all Commonwealth countries share. In the countries of the OECD there are an estimated 30 million unemployed. In the developing world, the lack of resources to pay benefit means that unemployment is not measured by the length of the dole queue; but it is nonetheless endemic in terms of the underemployment, sometimes chronic, of human potential. Fear of growing unemployment lies behind resistance to much of the introduction of new technology, especially that associated with microelectronics. For politicians, the prospect of robots and computer-based systems being used to replace labour in manufacturing cars or clothes, in harvesting cash crops, or in operating banks and government offices, is deeply worrying. I am sure this is what some Employment and Labour Ministers had in mind when they asked the Secretariat to convene a Group to examine the management of technological change. Yet, as the Group's Report brings out, the overall impact of technological change on employment has been historically positive and can remain so. New jobs are being created by the new technologies, both directly and indirectly, as more wealth is generated by improved productivity. In the past, technology has been a major source not only of higher living standards, but also of increased employment. There is no reason why this should not continue. Its achievement will be materially helped by suitable economic policies not least at the macro-level. Indeed, technology must not become a scapegoat for failures of economic policy which have led to high unemployment.

Among policy-makers in developing countries, emerging technologies are often regarded with apprehension. This is induced by a sense of

impotence; also by a feeling that what is appropriate in richer countries may not be so in poor ones. These fears are understandable. But the Group's Report gives abundant evidence that where technology is directed, and adapted, to meet the needs of low-income groups, it can be a powerful force for good, especially in agriculture and rural development, where in many forms it could be even directly employment-generating. And this is true not only of technology in its traditional forms, but also in relation to the emerging technologies. The successes of some Commonwealth Asian countries with 'green revolution' technology is a measure of the potential. I have been struck, too, by reports from the UN Women's Conference in Nairobi in July 1985 of the contribution which could be made to ease the arduous existence of rural women in developing countries by the diffusion of a few simple and well-established technological innovations in water filtration and the growing of subsistence food crops. Because of technology, human societies have it in their power to raise living standards worldwide and thus eradicate mass poverty and hunger. But the question of how to utilise that power takes us into politics and economics rather than into technology itself.

What can and should governments do? I hope this Report will be useful in suggesting practical guidelines to answer that question, while recognising that societies vary greatly in size, wealth, goals and needs. Unfortunately there has recently been an unhelpful degree of polarisation in the debate about the role of government, based on extreme positions on free market and planned societies. When it comes to technology policies these extremes are particularly unhelpful. There is clearly a major role for private entrepreneurs who will innovate and take risks, and who will respond to market incentives; this is especially true in small-scale agriculture. But there is also a critical role for governments: in basic research; in education and training; in building up a domestic R & D capacity, particularly in areas such as agriculture; in reordering priorities to take into account basic needs; and, through forecasting and assessment, in identifying those technologies which can be of benefit to society as a whole.

If the Report is to have enduring value it will be as a basis for action both at national level and through regional and wider multilateral cooperation. The Group expresses the hope that the Commonwealth could itself prove a suitable vehicle for education and training, technological cooperation, and information exchange. Where possible, we in the Secretariat shall endeavour to help in this field.

It gives me pleasure to present this Report, on a subject of great current relevance, to Commonwealth Governments and to the international community generally.

Shridath S. Ramphal

Letter of Presentation

Marlborough House,
Pall Mall,
London, SW1
13 July 1985

H.E. Mr. Shridath S. Ramphal,
Commonwealth Secretary-General
Marlborough House,
Pall Mall,
London, SW1

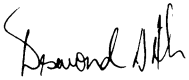
Dear Secretary-General,

You appointed us as a group of independent experts chosen from a wide range of Commonwealth countries. In accordance with the mandate given us, we have sought to examine the impact of new technologies, identify appropriate policy measures to facilitate adjustment to them, and suggest arrangements for sharing Commonwealth experience so as to enable member countries to derive maximum benefits from new technologies. We herewith present our Report, which we have signed in our personal capacities and not as representatives of the governments, organisations or countries to which we belong.

We would like to express our thanks to you for your confidence and trust in appointing us, and for the technical and administrative support your staff have provided us throughout our work.

Yours sincerely,

M. G. K. Menon



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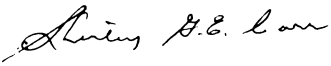

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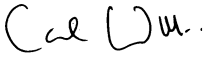

Carl Wright

Contents

Volume I

		Page
	PREFACE	1
PART I	INTRODUCTION AND SUMMARY OF RECOMMENDATIONS	3
	I. The Emerging Technologies	3
	II. The Impact of New Technologies	5
	III. Technology Policies: the Approach of the Group	9
	The need for strategies to harness new technologies	9
	A 'systems' approach to new technologies	11
	Technology for people	12
	A differentiated approach	14
	IV. Summary of Policy Recommendations	15
	Essential tasks for government	15
	Decision-making machinery and technology	18
	Creation of an indigenous capacity	19
	Technologies for basic needs	22
	Adjustment policies	23
	Importing technologies	25
	International cooperation	25
	Commonwealth cooperation	28
PART II		
CHAPTER 1	THE IMPACT OF NEW TECHNOLOGIES	31
	I. Development and Application of New Technologies	32

		Page
	Microelectronics	32
	Biotechnology	35
	New materials technologies	38
	Renewable energy technologies	40
	Other new technologies	41
	II. Economic and Social Effects of New Technologies	42
	Economic growth	42
	Employment	46
	International trade	55
	Social matters	64
CHAPTER 2	TECHNOLOGY POLICY: PRINCIPLES, EXPERIENCES AND PROSPECTS	72
	I. Introduction	72
	II. A Strategy for Managing Technological Change	75
	Technology forecasting	75
	Technology assessment	77
	Information infrastructure	78
	Policy coordination	80
	Financing technological change	80
	III. Policies to Increase Indigenous Technological Capacity	80
	Priorities and points of entry	80
	Education and training	82
	Indigenous research and development	85
	Developing links between R & D and production: technology diffusion and innovation	88
	Support for indigenous new technology products	92
	IV. Managing Technology for Social Needs	94
	Technology for basic needs	94
	Technology assessment and wider social impacts	95
	V. Managing Adjustment to Technological Change	97
	Economy-wide policies	98

		Page
	Education policies and adjustment assistance	98
	Regional policies	100
	Labour relations and conditions of work	100
	Adjustment policies of particular concern to developing countries	101
	Manufactured exports and trade policy	103
VI.	Managing Imports of Technology	105
	Direct purchase or acquisition	105
	Purchase of imported hardware	106
	Foreign investment	108
	Alternative forms of collaboration with multinational companies	109
	Importing 'know-how' directly	110
Table:	Characteristics related to technological capacity in selected countries	112
CHAPTER 3	INTERNATIONAL COOPERATION IN TECHNOLOGY AND THE ROLE OF THE COMMONWEALTH	114
I.	Introduction	114
II.	Areas for International Cooperation	115
	Education and training	115
	Joint research and development	117
	Technology policy formulation	119
	Acquiring capital goods	120
	Other areas for cooperation	121
III.	Areas for Commonwealth Cooperation	123
	Information and promotion activities	124
	Advisory services	126
	Training and exchange programmes and education	126
APPENDIX 1	ABBREVIATIONS AND GLOSSARY	130
I.	Abbreviations	130
II.	Glossary	131
APPENDIX 2	TERMS OF REFERENCE	135
APPENDIX 3	MEMBERS OF THE WORKING GROUP	136

Preface

At their 1982 and 1983 meetings, Commonwealth Employment/Labour Ministers discussed how the diverse societies of Commonwealth countries might best realise the benefits of, and accommodate the changes from, applying new technologies, as well as learning from each other's experience in this field. They identified the management of technological change as being of critical importance in a context where rapid innovations in technology coincided with generally sluggish economic growth, so that technology seemed to threaten existing employment although offering the potential, at least, for economic revitalisation. They recommended to Commonwealth Heads of Government the establishment of a working group to examine member countries' experience in managing technological change to assist these countries in their planning, training and adjustment strategies. At New Delhi in November 1983, Heads of Government endorsed the Ministers' recommendation and confirmed the draft terms of reference submitted by the Commonwealth Secretary-General (see Appendix 2).

The Secretary-General constituted our Group in early 1984 and we met on four occasions before finalising this Report. At our third meeting we requested the Secretariat to report, on our behalf, to the June 1985 Meeting of Commonwealth Ministers of Employment/Labour, setting out the type of analysis we had been undertaking and the direction in which our thoughts were leading on those parts of our mandate which come within the purview of Ministers of Employment/Labour. In addition our Chairman addressed the Meeting. Ministers discussed his statement and the Secretariat's report, and made a number of comments which we found most useful. Our deliberations also benefited from papers drafted and presentations made by three consultants—Mr. John Evans of the European Trade Union Institute, Mr. Kurt Hoffman of the Science Policy Research Unit, University of Sussex, and Mr. N. P. Singh, Secretary, Technology Policy Implementation Committee, Government of India—to whom we would wish to express our thanks. Some of these papers will be published separately by the Commonwealth Secretariat.

Our Report is in two volumes. In Volume I we first set out our general approach and summarise our recommendations. We then examine the evidence and consider the issues in more detail. Chapter 1 analyses the impact of new technologies on the economies and societies of countries, particularly developing countries, and concentrates on economic growth, employment and international trade. Chapter 2 spells out the policy implications of that analysis, and considers the principles and experiences of technology policies. Chapter 3 examines areas for international cooperation in technology and suggests a role for the Commonwealth in helping member countries to realise the economic and social benefits which new technologies can bring. In Volume II we annex some detailed technical material which complements the main body of the Report and which we felt will be useful for reference purposes.

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.

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.

Chapter 2

Technology Policy: Principles, Experiences and Prospects

I. INTRODUCTION

2.1 In this chapter we shall endeavour to spell out the policy implications of the analysis of the effects of new technologies made above. However, the question of appropriate policies for the management of technological change cannot adequately be discussed at the level of global generality. Countries vary enormously in their technological capacity and needs because of differences in size, living standards, stocks of scientific and other trained manpower, and resources. Within the Commonwealth 27 out of 49 countries have a population of under one million each; by contrast India has almost 700 million people and almost three million trained scientists and technologists. If we look at economic resources, crudely measured by GNP, which limit the scale of expenditure on R & D, education and training, Ghana has a GNP a little over one per cent of that of Britain, whose economy is in turn less than half the size of Japan's and a seventh that of the United States. Yet ten Commonwealth countries have economies less than or around one per cent of the size of Ghana's. Thus between the United States, on one hand, and a small Caribbean or Pacific island, on the other, there is a size differential of 50,000 or 500,000 to 1. Table 2.1 (at the end of this chapter) illustrates the differences in technological capacity. Furthermore, governments differ very considerably in their goals, priorities and ideology. Clearly, it makes little sense to prescribe identical policies for countries with such widely different characteristics.

2.2 From the table a rough classification can be made into six country groups:

Major developed economies

2.3 These account for most global expenditure on new technology and have most of the high-level scientific and technical manpower. They are usually substantial net exporters of technology in the form of goods, foreign investment or through direct sale. In these countries—the United States, Japan, Germany, France and Britain—a major technological priority is developing an innovative capacity across a variety of emerging technologies. However, even among these large and advanced economies, this process involves drawing heavily on imported as well as indigenous sources of technology (except for the United States and, increasingly, Japan), and recognition of the need for collaboration is reflected in the European 'Esprit' programme. There are also substantially different approaches. The French and Japanese are making maximum use of government-private sector collaboration, and government indicative planning. Others, particularly Britain, are relying more heavily on private sector judgements of risk and are providing support mainly through defence and other contracts and modest direct assistance, as in the British 'Alvey' programme.

Medium or small, open, developed economies

2.4 Many rich countries are, in aggregate, substantial net importers of technology. Relatively small population, in the context of an open economy, is associated with specialisation and a comparative trading advantage in resource-based activities (as in Australia, Canada, Norway) or specific high-value-added manufactures (Sweden, Netherlands, Switzerland, Austria). These countries have become materially rich, but lack a strong technological base. They have made less attempt to formulate technology policy explicitly—given that it is more likely to be reactive than proactive—although the Myers Report in Australia did set out the options for maximising the benefits and minimising the costs of technological change in an essentially open economy context.

Newly industrialising, outward-looking, countries

2.5 In Asia, there are a growing number of newly industrialising countries (NICs) which have achieved rapid economic growth associated with exports of manufactures, utilising labour-intensive technological processes and/or standardised products. Japan pioneered this form of development but has progressed well beyond it, as Singapore and South Korea now appear to be doing. The pattern is becoming established in Thailand and Malaysia, and is now being adopted more widely in low-income Asian countries and elsewhere. Such societies, like small open developed economies, are characterised by a predominant dependence on imported technology. But they have lower living standards and are

at an earlier stage of the transition from industrial to post-industrial patterns of employment and social organisation.

2.6 While these countries are at different stages of technological development, there are some commonly expressed priorities. They include:

—gaining access to the best internationally available technologies through developing an information infrastructure and facilitating foreign investment and licensing arrangements;

—using new technologies to strengthen labour-intensive manufacturing activities and, for the more advanced NICs, to upgrade production and develop new capital- and technology-intensive exports; and

—training people to meet the skill demands from export industries, including services and high-tech products as well as traditional goods.

Populous developing countries with substantial technology base

2.7 India and China are important, if somewhat special, cases of countries which are poor in income terms but have a large and diversified technological base, are self-sufficient in many areas of technology and are even exporters of capital goods and trained people. There are some common features with the NICs in Latin America (notably Brazil or Mexico). Indian and, where they are known, Chinese priorities have been in two areas. One has been to build up an indigenous technological capacity across a wide front, especially in relation to food, energy and weaponry, but taking in selected aspects of emerging technologies, mature technologies and village artisan technologies of a traditional kind. A second has been to control, quite severely, access to imported technology where this is deemed 'inappropriate' because it is, relative to indigenous alternatives, labour-saving or exposes domestic substitutes to strong competition. There is, however, growing recognition that even for countries which have developed substantial self-sufficiency in technological terms, considerations of economic efficiency are causing countries to import many technologies rather than develop them independently.

Low-income countries with limited technology base

2.8 In most of sub-Saharan Africa and some other developing countries (Bangladesh, for example), poverty is associated with a high level of dependence on imported technology in almost all non-subsistence sectors and a limited stock of educated and technically trained

people. In the case of sub-Saharan Africa, long-term policy objectives also have to be located within a short-term context of extreme economic and social crisis, including widespread hunger and falling per capita incomes. Under such circumstances there are short-term pressures to reduce whatever indigenous R & D is taking place. But the crisis is creating its own technological priorities, particularly the development and diffusion of high-yielding foodgrain seeds appropriate to African climatic conditions, and the rapid development of a local capacity to supply spare parts and basic inputs to industry to mitigate severe bottlenecks. Over a longer time horizon the focus of technology has centred on building up a capacity for evaluating, operating and adapting imported technology, involving controls on the indiscriminate use of imported equipment. Many problems are shared with the next group of countries.

Small, open, developing countries with limited technology base

2.9 Small states, the islands of the Pacific, the Caribbean and the Indian Ocean, have a high degree of dependence on imported technology. For them, technology policy involves the selection of a small number of high priority areas for technology development where the acquisition of local competence is crucial, possible and inexpensive, with a strong emphasis on regional collaboration to spread the overhead costs of R & D, training and education. Where there is reliance on foreign technology, small states can develop a capacity for gathering information, forecasting major technological changes which affect principal export products, selecting appropriate technology imports, bargaining, disaggregating imported technology into 'core' and peripheral elements, and absorbing technical knowledge.

II. A STRATEGY FOR MANAGING TECHNOLOGICAL CHANGE

2.10 All governments require some capacity to forecast, assess and monitor the impact of technological change. While the effects of new technologies have a certain measure of inevitability, many problems and future needs can be anticipated and contingency planning can be carried out. This argument in no way implies a commitment to centralised, bureaucratic, decision-making. It does, however, imply that governments can usefully develop some capability in the following areas.

Technology forecasting

2.11 New technology is a field of rapid change and uncertainty. Even where scientific knowledge has been converted into a practical

technology which can work outside of laboratory conditions, the market response to an innovation cannot easily be predicted. Thus, governments cannot forecast with precision the magnitude and direction of technical change. Nonetheless, especially for those countries which are technological followers—i.e. which are not at the frontier of innovation in emerging technologies—it is possible to predict change on the basis of what is already occurring in other countries.

2.12 It is possible, as we have shown in the previous chapter, to see the outline of the threats posed by advances in automation technologies to some labour-intensive manufactured exports from developing countries and by advances in biotechnology and new materials technologies to traditional commodity exports. The adjustment problems posed by these changes, especially for highly specialised economies, can be reduced (or new opportunities created) if they are expected and the necessary plans made. Or to take another instance, a major impediment to the diffusion of many microelectronics applications—information technology in particular—is proving to be the lack of people with the capacity to design and operate systems in which the hardware can be productively employed. Knowing this, developing countries can concentrate scarce resources in training people in 'software' and 'systems' appropriate to their needs.

2.13 There are many ways in which even a limited commitment to technological forecasting can provide a useful input to planning: to create public awareness of impending changes; to help markets to function by providing information; to clarify choices. The advice and direction given to Japanese industry by MITI in the 1950s and 1960s and, latterly, the less direct guidance in the form of 'visions'; Swedish restructuring in the 1970s based on government and industry projections; French 'planification': all represent variants of technology forecasting. These experiences have also pointed to the dangers of governments generating cumulative errors and weakening competitive attitudes among businessmen, and also of the difficulties in assembling data; though the OECD has broadly endorsed the value of such projections in reducing uncertainty in market economies. In developing countries there is less experience of technological forecasting, though such countries as Singapore, South Korea and India appear to be succeeding in different ways in developing a forward-looking capacity. In the case of Singapore, the mechanism in very informal; in India a more structured process is being built involving overall projective planning for technology, sectoral forecasting and plant level forecasting for large enterprises. For countries which are very small the labour resources available are more meagre but could be augmented by collaborative effort on a regional basis and through technical assistance. Indeed, small states, usually dependent on one export product, are in

particular need of early warning of technologically-induced changes which affect them.

Technology assessment

2.14 There are many important decisions which have a major bearing on the speed and impact of technical change: public sector contracts for defence, communications, information processing and construction; the choice of imported equipment and services under aid projects; the provision and orientation of secondary and higher education; the scale and approach of support services for farmers and businesspeople; priorities in foreign exchange or credit allocation when these are rationed; approvals for major foreign investments. It is important that the technological implications be assessed, even if they are unintentional.

2.15 Moreover there are important reasons why major decisions involving new technology should be informed by a system of technology assessment which goes beyond the normal accounting or engineering criteria, and which is not left to individual plants, firms or government departments. Technology assessment is necessary:

—where there is a range of options. New technologies which are relatively capital- and import-intensive in a developing country context are likely to be used unless adequate allowance is made for the way in which prices normally undervalue capital and foreign exchange and overvalue labour. Social cost-benefit analysis is a recognised tool of project assessment in these conditions;

—to encompass the wider implications of new technologies. These include the impact on the environment and on working and living conditions, even if they are not necessarily quantifiable; and

—to look at the 'systems' implications of employing new technology. Whether, for example, the administrative structure of public sector agencies is such that the new technology can be efficiently used and maintained, and how much additional training and expatriate labour is required to make the system effective.

2.16 Technology assessment is now being adopted as a necessary activity in several countries; Malaysia, for example, now gives it a substantial role in the economic planning process. A capacity to carry out technology assessment should not imply a process of detailed, time consuming, and bureaucratic regulation. It should apply primarily to major commitments. Nor is great sophistication necessarily required. Indeed it is an activity which should not be confined to large countries with sophisticated planning systems; for a small Pacific or Caribbean island state, a decision to computerise the main bank or to introduce

automatic harvesting techniques in the plantations of the major crop has far-reaching implications which merit serious assessment.

Information infrastructure

2.17 Without adequate information on new technologies, technological change will be retarded or distorted; neither market mechanisms nor planning will work efficiently; and both technological forecasting and evaluation will be limited in their usefulness. Many developing countries are particularly disadvantaged in their capacity to benefit from, and adjust to, new technologies because of the lack of information available to medium- and small-scale entrepreneurs, scientists and engineers and state officials. This disadvantage arises from several factors:

—nearly all R & D, innovation and technology monitoring takes place in developed countries;

—technology selection among a vast profusion of inventions and applications is, in itself, a difficult, highly skilled and costly activity;

—much new technology is 'privatised' by large companies and subject to property restrictions;

—even where new technology is not so restricted, it is increasingly subject to user charges as a result of being stored in computer systems rather than being available more cheaply from technical journals; and

—even where information on new technology is made available to large firms, government officials and scientists in a developing country, it may be extremely difficult to disseminate it. The main potential users are small, often scattered, and usually ill-educated farmers, businesspeople and traders in the 'informal economy'.

2.18 For these reasons most developing countries have very weak systems for locating, acquiring, analysing and repackaging scientific and technological information and disseminating it to potential users. Governments can try to upgrade information infrastructure in a variety of ways.

2.19 *First*, much can be done through the collection and dissemination of information in national technology registries, data banks, information and documentation centres and specialised libraries, and by arranging access to external data bases. Governments can also commission studies and support survey missions abroad as well as collect, process and transmit information. Even the administration of Hong Kong, which intervenes sparingly, has set up government offices to help industrialists find new foreign technology. However, firms require very

specific kinds of information to assist them in making strategic decisions. Only they possess the expertise to articulate these information needs and to 'filter' what is available according to their specific requirements. Hence they must ultimately carry out a large share of this monitoring effort themselves, either individually or collectively. Such efforts are expensive, however, and here a programme of state subsidies can be used to defray the costs.

2.20 Despite the potential for information gathering, most developing countries have serious deficiencies in this area. Highlighting them and recognising the human resource limitations of most of these countries, a UN report[1] has suggested a collaborative approach, on an international and regional basis, for gathering information in specialised areas of particular concern.

2.21 *Secondly*, the availability of information depends on the terms of technology transfer through foreign investment, licensing, consultancy or other means. This is because much of the most valuable new technology—for example, biotechnology applications in health and agriculture—is subject to property restrictions and is available on terms which reflect a degree of monopoly in supply. Where information gathering can help is in assessing the market conditions affecting suppliers of technology, as these might be an important influence on the type of technology available and the conditions under which it will be offered. A careful survey of technology markets will reveal which firms may be willing to provide the technology on 'good' terms. Many firms in the NICs have successfully monitored markets in this way to strengthen their negotiating position. We shall deal later in more detail with questions of technology transfer and the need for developing countries to have a capability to acquire imported technology on advantageous terms. A related issue is patenting. Whatever advantage patenting may serve in stimulating innovation in industrial countries, its effect in developing countries is invariably to arrest the dissemination of technological information, much of it from abroad.

2.22 *Thirdly*, governments can play a major role in the domestic economy by improving information flows to indigenous small and medium-size entrepreneurs. Government-sponsored extension services have been a critical ingredient in agricultural innovation in developing countries, and have a role too in manufacturing, particularly mechanical engineering, where experienced engineers and production personnel can advise on the use of machines and work organisation. But such advisory and information support services can only work in the context of a general economic climate conducive to risk-taking and in conjunction with an easy availability of technological and other inputs.

Policy coordination

2.23 Societies, and governments, which approach new technology passively and in a piecemeal, uncoordinated, way are likely to achieve the worst of all worlds: the painful adjustment costs without the compensating benefits.

2.24 The minimum contribution which governments can make to engender a more integrated approach to technological change is to try to ensure that its own activities are coordinated and consistent: for example, to ensure that its education and training policies are aligned with the changing needs of agriculture, industry and services; and that there is consistency between trade and domestic competition policies. Whilst different governents will approach coordination in different ways, we would suggest that there is need for an independent unit within government which can take a wide view of the public interest and report directly to the central decision-making authority: the President, Prime Minister or Cabinet. The machinery is not important in itself—some governments have elaborate structures for technology policy which do little. Rather, what is needed is political acceptance that the management of technological change is a crucial task of governments.

Financing technological change

2.25 Creating a capacity to forecast, assess and monitor the impact of technological change will require financial resources as well as a coordinating unit in government. Equally important is the need for funds, usually on a much larger scale, to effect technological change itself. This involves financing not only R & D and other aspects of technology commercialisation but also the more expensive process of investing in capital equipment that incorporates new technology. Government assistance is often needed both for technology R & D and for diffusion and innovation, and a strategy for managing technological change should include mechanisms to promote each. We consider these issues further, in a later section (paragraphs 2.41–2.43 and 2.44–2.57, respectively).

III. POLICIES TO INCREASE INDIGENOUS TECHNOLOGICAL CAPACITY

Priorities and points of entry

2.26 For all societies, the ability to use new technologies and manage them in accord with social goals depends on the extent of indigenous

technological capacity. A comprehensive technological capacity involves mastery of a wide range of new and established technologies. Its acquisition is clearly a long-term and complex process. Most poor countries, and especially the smaller of them, have very little capacity. Faced with a succession of new technologies superimposed on existing mature technologies, they have to make choices as to the most useful point of entry. Choices arise in identifying the relative emphasis which should be placed on acquiring a capacity for basic scientific research, producing the technological hardware, systems design, or diffusion and adaptation of externally acquired technologies.

2.27 The choice clearly has to be based on national needs and then on the costs of different options. For low-income countries in Africa and South Asia, agriculture is likely to be the area of major priority, drawing mainly on the mature technologies and increasingly on biotechnology. The nature of biological science and technology, especially in relation to mature technologies, is such that for many developing countries it is feasible to carry out not just technological diffusion and adaptation but important aspects of basic biological research. In some cases—for example the detailed study of local plant life—such work is essential to the creation of an indigenous capacity.

2.28 But in the case of other technologies—for example microelectronics and its applications in industry and services—a quite different set of considerations apply. There are major barriers to entry in terms of the high cost of R & D and of production in respect of semiconductors, mainframe and mini-computers; arguably, even micro-computers. Except for countries whose domestic markets are very large, and indigenous electronics technology advanced, the cost of protecting the production of indigenous hardware, rather than importing it, is likely to be very considerable. Moreover, the movement in relative prices suggests that, internationally, there is a long-term relative scarcity of software skills and a relative abundance of hardware, implying greater savings from the indigenous development of the former rather than the latter. Nor is it just a question of cost; software is much more user-specific than hardware for components, making it more essential for there to be an indigenous capacity to adapt software to local applications. This is also becoming more feasible as software becomes more compatible as between machines, giving greater scope to independent software firms. Arising from these considerations, the most productive point of entry in the computing industry may be 'systems' integration; that is, combining standard, imported, hardware with software packages adapted to specific end-users' needs. To develop such a capacity, however, would make heavy demands not only on indigenous programming skills but on training to upgrade these skills constantly, and an ability to monitor and analyse trends. Whatever the particular technology, investment in human capital in general—in education and

training—will almost certainly be more crucual to developing an indigenous capacity than investment in hardware. To this issue we now turn in more detail.

Education and training

2.29 There is a generally recognised need for high priority to be given to human resource development, through education and training, in order to make effective use of new technologies; but there remain many practical questions of method and emphasis. For example, in certain areas, such as peasant agriculture, a capacity for innovation is related to general literacy allied to vocational experience and entrepreneurial flair. But some areas of modern technology, particularly electronics, depend heavily on formal and specific training. The following major distinctions can be made.

New types of sophisticated skills

2.30 The demand for specific skills will naturally depend on the technology concerned. For example, in biotechnology heavy additional demands will be made in certain areas. They include:

—staff trained in the biological sciences to develop the underlying biological know-how related to local conditions;

—personnel for biotechnology R & D work, including specialised laboratory technicians;

—process engineers for the manufacture of biotechnology products;

—agricultural extension workers, linked to field stations, able to educate potential users of new seed and plant varieties; and

—paramedical staff trained to make best use of preventive medicines, diagnostic agents and new curative drugs.

2.31 The microelectronics revolution also is creating a new set of demands for a skilled workforce. They are giving rise to a need for:

—basic software training for a large number of managers, researchers and operational staff;

—electronics-related course work in higher education—polytechnic and university degree course—to marry traditional professional skills and electronics/software capabilities;

—specialised training for programmers, designers and managers. Systems designers are crucial in developing countries, to allow product development without the need for component design skills, and are essential for effective use of new computing systems. Other aspects required for effective software development include

programme and data-base designers, and specialists in operational research and mathematical logic;

—on-the-job training for manual workers who are required to operate electronically controlled devices, so as to equip them with basic skills in programming and logic rather than 'blue collar' craft skills (though these may remain relevant in a modified form); and

—a repair and maintenance capability, the lack of which is extensive in most developing countries and accounts for much underutilisation of plant capacity. The problem is becoming more acute with the replacement of mechanical devices by microprocessors, requiring electronic maintenance.

2.32 This classification of employment training requirements is, of course, merely illustrative and refers only to specific new technologies. Finally, we should emphasise that though the application of these new technologies is creating some bottlenecks in skills, in other cases they may be reducing the demand for traditionally scarce skills (in developing countries, for example, a reduction in the need for specialists to check, control and repair complex machines because of self-diagnostic devices).

Technology awareness and scientific literacy

2.33 A long-term strategy to develop an indigenous technological capacity will rely not only on specific training but on a broad awareness of the possibilities of new technologies and the scientific principles underlying them, starting with the *school system*. Without basic literacy, numeracy and scientific education, technological training is likely to be superficial and ineffective. This implies giving a high priority in the basic syllabus of primary and secondary schools to relevant disciplines, particularly mathematics; ensuring the secondary-school system is able to prepare an adequate number of students for higher education in engineering and natural and agricultural sciences (UNESCO has calculated that as few as 10 per cent of African students are in these disciplines); and introducing familiarisation with computers at an early stage (for example, Singapore has developed learning kits for school-level instruction).

2.34 Technological awareness and an ability to understand technological possibilities and limitations is important among *decision-makers*. These have a need for general and specific training in two respects:

—to apply new technologies to improve the delivery and efficiency of public services; and

—to sensitise personnel to the opportunities for new technologies and the implications of technology choice.

Skills for those outside the formal economy

2.35 An important impact of new technologies will be on illiterate or largely uneducated farmers or artisans and those living on the fringes of urban life in the informal sector. This impact could often be made more positive through 'blending' new technology with traditional methods, as we have discussed above. The process of 'blending' requires some degree of 'training by doing'—through demonstration projects and extension work. There is also more demand for vocational training of the type developed in India by the Small-scale Research and Development Organisation to train rural youth as—for example—cycle mechanics and fitters. Since innovation involves entrepreneurial as well as technical decisions, an important additional element in training for small businesspeople and farmers is of basic business skills: bookkeeping, for example.

Using technology to teach technology

2.36 The training and education requirements to adapt to new technologies are so great that it is difficult to see traditional teaching and training methods being adequate. New information technology, however, provides the means to teach and train as well as being a subject in which to be taught and trained. Satellite communications now extend the teaching of basic literacy, preventive health and agricultural methods by beaming television pictures into remote villages in India; vocational training programmes for nomadic pastoralists in Botswana make use of micro-computers for clerical and management purposes and for communicating basic business and craft skills. Where new teaching methods can be made cost-effective and the software skills acquired to operate them efficiently, there is a dual advantage of simultaneously teaching and training while raising awareness of the potential of new technologies.

Retaining scientific and technical workers

2.37 Increasing the supply of educated and trained people is only one step; another is retaining them. A dilemma particularly for developing countries (though it is more general) is that if resources are put into scientific and technical education, especially at graduate level, there is a danger that these will be lost. This can occur as a result either of emigration—the 'brain drain'—or of diversion to more personally satisfying or lucrative activities, in administration for example. Emigration is a particular danger where extensive overseas training and education occurs. Misdirection of workers will be common where the economy fails to expand rapidly enough to absorb trained personnel. The crisis in African development, for example, has had a particularly

severe impact on the funding and morale of research and higher education institutions. A UNESCO study has shown that in Africa, out of 1,200 qualified research scientists, only 9 per cent are now employed in scientific and technical jobs. The solutions to these problems are clearly complex and long term but, unless there are economic inducements and professional incentives in the form of freedom to carry out research and publish the results, the mere creation of more trained personnel may be offset by a loss of others more experienced.

Who pays?

2.38 Before leaving the question of training and education the issue needs to be raised of 'who pays?'. While there may be a general long-term national interest in acquiring a labour force trained and educated to use new technologies, the short-term beneficiaries are the trainees themselves—a relatively privileged group in most societies—and the companies who employ them. While there are complex issues of educational and economic policy involved, several general points might be borne in mind:

—any transfer of high-technology 'hardware' from abroad in the form of equipment or direct investment should be accompanied by an obligation to train, or finance the training of, local nationals in the vocational skills needed to operate, adapt and otherwise improve the hardware;

—much training can be managed using what is now called the 'driving test' principle; that is, the government sets standards and carries out examination and testing, while the private sector undertakes the training on a competitive basis;

—state supported vocational training can be financed through a cess or levy on beneficiary companies, based on their turnover or workforce, so that those which derive the greatest net benefit will make the greatest commitment to train their staff; and

—few, if any, developing country governments, and only some in developed countries, can afford free education at secondary or higher levels. The system of fees and/or loans which is then required can be used to discriminate actively in favour of disciplines needed to develop a scientific and technological capacity.

Indigenous research and development

2.39 Research and development can be carried out formally, in laboratories, or—of great and underestimated importance—by small-scale adaptations in the field. There are certain areas which appear to be urgently in need of more R & D, of both kinds, in developing countries:

—adaptations to existing technologies through 'blending' or other improvements which involve capital stretching, and reducing the optimum scale;

—improvements in tropical foodgrains such as sorghum, millet and maize, pulses, and root crops such as cassava;

—developments in biotechnology, especially the accumulation of location-specific biological knowledge; vaccines against tropical diseases; protein-rich food sources; alternative sources of energy; new uses for traditional raw materials; and

—utilisation of marine resources.

2.40 There are well-documented cases of successful research which have led to innovation on a significant scale in developing countries: the progress of India's research laboratories in utilising low-grade coal and metallic ores, in upgrading the leather industry, and in developing a multipurpose food additive; the use of indigenous plants in Mexico; ethanol-powered motor vehicles using sugar cane in Brazil; small-scale cement, paper and chemical plants in a variety of countries; biogas production; new construction technologies; solar pumps, wind-powered generators—and many others.

2.41 The central problem for developing countries is that very limited funding is available for indigenous R & D. In particular, despite the value of agricultural research, a survey of over 50 developing countries showed that they spent on this less that 0.5 per cent of the value of agricultural output—as against one to two per cent of much higher output in developed countries. There is, moreover, likely to be only a limited contribution from the domestic private sector; even in the handful of exceptions, like India, South Korea or Brazil, where indigenous enterprises are reasonably well developed, their interests are primarily concerned with R & D on industrial technologies. There is always a danger in these circumstances that the few public resources that are available are spread too thinly and misdirected.

2.42 There is not a great deal that can be done in the short run to narrow the massive disparities between developed and developing countries in relation to R & D expenditure (see Table 2.1 at the end of the chapter). As a rough rule of thumb, UNCSTD set a minimum target of one per cent of GNP for developing countries to spend on R & D by the end of the 1980s, though they are very far from reaching that level. The only advantage which developing countries have as a result of lagging so far behind in R & D expenditure is the opportunity for 'leapfrogging' as a result of acquiring the results of existing R & D. But there has also been criticism that even the R & D which developing

countries do undertake produces little of commercial value, and that their research institutions are not particularly effective. Surveys of research centres[2] have found that, in general, those in developing countries are strongly influenced by orientations in developed countries and do not undertake activities relevant to domestic problems; that coordination is usually poor, both nationally and internationally; researchers, especially in practical applications, have little security, low status and low pay; monitoring and evaluation are negligible; and there are constant operating problems because of inadequately trained support staff, shortages, lack of maintenance, and mismanagement.

2.43 Thus, a paradoxical and unhappy situation exists where the potential areas of useful and original R & D which could be conducted in developing countries far exceed the resources available to almost all of them, but where there is considerable dissatisfaction that the R & D carried out fails to meet expectations. A variety of remedies can be tried:

—stricter priorities for the work of public sector institutions. These should be based on felt needs and could be defined by a national advisory body on science and technology or by sector-specific bodies. The dangers of centralisation, however, have to be borne in mind, notably the threat to creativity and independence;

—collaboration. Much successful R & D depends on having teams of disparate skills built up over a period of time. This may require a substantial scale and reliable funding. Many of the problems arising for small-scale, under-funded, research could be resolved through greater collaboration between research institutions in different centres;

—a mandate to most government-sponsored research institutions (including university departments) to concentrate on development work in priority areas. These areas also should be based on felt needs and may include items which, at first sight, seem minor and pedestrian: research into methods of maintenance and repair, local manufacture of spare parts, food preservation to reduce wastage;

—a system of regular, outside, evaluation of public research agencies, including inter-country evaluation drawing on successful 'model' institutions elsewhere. In developing the concept of 'model' institutions, however, what may be required are those which are not copies, with minor variants, of developed country institutions but, rather, bodies with radically different goals;

—insistence on a high proportion of contract research (though not necessarily on a profit-maximising basis, as when the clients are small farmers, artisans, informal-sector manufacturers and poor householders); and

—encouraging in-house work in private firms through, *inter alia*, tax concessions. In India, for example, in-house R & D expenditure has risen almost ten times in the last decade and now involves almost 700 industrial units, encouraged by a variety of fiscal reliefs including a direct tax concession of 100 per cent of current R & D expenditures. In Malaysia, the breakthrough in cloning technology as applied to oil palm and coconut palm has also been achieved by private sector R & D.

Developing links between R & D and production: technology diffusion and innovation

2.44 Even if laboratory work is of high quality, relevant and on a substantial scale, there is frequently a breakdown in the linkage between R & D and production; that is, there is a failure of innovation rather than of invention. There are two areas of policy which might remedy this deficiency.

Assistance for technological diffusion

2.45 Where new technologies are available there may be difficulties in transferring them to small-scale users because of deficiencies in credit, organisation and marketing. It is, for example, possible to envisage many low cost applications of microelectronics in the health, education, energy and food sectors of developing countries. But, although the costs of the hardware may be low and falling, the packages and peripherals are still expensive. In this sense, microelectronics has much in common with the high-yielding seed varieties of the 'green revolution'. It is information-intensive, technologically sophisticated and, though cheap in itself, highly dependent on costly auxiliaries such as sensors, software and peripherals to be truly effective (just as 'green revolution' seeds need complementary irrigation and fertilizers). For these reasons, though the total investment costs of new technology may not be particularly large, they may be too high for the manufacturer in the informal sector of developing countries or for the subsistence farmer. Thus new technology—and the associated improvements in productivity—may be restricted to large firms and large farmers, especially in the early years when it is relatively more expensive, unless there are facilities to share the scale-intensive services and equipment.

2.46 There are many ways in which governments can catalyse private sector activity among small firms. They can:

—provide or promote special credit schemes for small farmers and businesspeople whose needs have been neglected by banks. This is especially important where small-scale users cannot afford even those new technologies which have been designed for them through 'blending';

—sponsor the extension services which have been a critical ingredient in agricultural innovation in developing countries;

—provide experienced engineers and production personnel to advise on the use of machines and the organisation of work in the manufacturing sector (as in South Korea); and

—support the establishment of engineering consultancy services to advise on the choice of technology, make project reports, provide management and training (as with Engineers India Ltd.), and operate turnkey plant. Such services are often crucial to making linkages between R & D and local industry.

2.47 It has to be recognised, however, that government extension and support services often have the same problems of ineffectiveness, low status and lack of competence as have R & D institutes. The best vehicle for diffusing technology may well be non-government institutions; if private initiative is not forthcoming, then cooperatives and voluntary, non-profit, local associations may be needed. These can be helped to operate through acquiring access to credit. But where these institutions are weak, responsibility will fall on governments. Sensitivity to user needs could be achieved if technology centres were established and equipped with R & D facilities—or testing systems, or computer programming facilities—that could be leased. Firms would then be able to develop experience in dealing with or using new technologies without undertaking the risks of ownership. Staff at such centres could be seconded, with private sector personnel moving in and out even at the more senior positions. This would remove some of the problems of bureaucratisation and inflexibility that can arise in public institutions.

Creating a climate for innovation

2.48 Technological change is closely related to investment. Education, training and R & D will not produce significant returns to society until the adoption and diffusion of new technologies is made possible through new investment. Creating a suitable climate for innovation, therefore, requires creating economic conditions for risk-taking and investment, while simultaneously drawing on a strong infrastructure of research and training. For many developed countries this is difficult enough to achieve. For most developing countries, especially small states, which have a very limited technical infrastructure and, often, severe economic problems stemming from external shocks, it is even more difficult. The policy implications can be broken down into more specific elements.

Venture capital

2.49 For countries without fully developed capital markets, there is a need to attend to the problem of venture capital. This has been identified

as a barrier to technological advance in many developed countries (such as Britain and Australia) as well as in developing countries. Many governments have encouraged banks or created special agencies to give credit lines or equity for R & D and related commercial activities. However, in practice, these credit lines often prove ineffective, unless they are concurrently supported by suitable under-writing or loss-insurance schemes. They can also be costly to the public purse. Credit control and preferential credit is also being used—as in India—to introduce a variety of technology-related criteria into the policies and procedures for evaluating loan applications by financial institutions. An entirely different approach to venture capital, favoured in the United States, is to give no special considerations but to impose low taxes, so giving an incentive to successful innovation rather than to innovation *per se*.

Competition and monopoly policy

2.50 Governments are pulled in two directions. Innovators would like their risks to be reduced by operating in a sheltered monopoly environment; there are, however, broader grounds of public interest favouring freer competition. In most developing countries the choice is often more painful, since the resistance to innovation may be greater than in developed countries while the dangers of monopoly control, especially by large foreign firms, are also greater.

2.51 A particular focus of attention is *patents* policy, which systematically protects innovators from competition until the technology has been profitably developed; *trade marks* have a similar role in relation to product design. As developing countries develop more technology indigenously, pressure grows for legislation to protect the property rights of private innovators. A balance has to be struck between granting an adequate period of protection while not, in so doing, inhibiting the diffusion of technology, especially in such socially sensitive areas as food and medicine.

2.52 Considerable care needs to be exercised in this area, however. In countries where indigenous innovation is weak and foreign enterprises are strong, local law is often used to protect the patents of foreign companies. This is of particular concern in biotechnology where there is a trend towards privatisation of knowledge under the control of a relatively small number of multinational pharmaceutical and petrochemical companies, so locking users into a 'package' of seeds and associated inputs (such as fertilizers and insecticides). It requires multilateral action for developing countries to obtain easier access to new technology patented in developed countries; but developing countries' own patent laws, covering, for example, new plant varieties and new products,

processes and life forms developed through biotechnology, can compound restrictions on access to technology. Domestic innovators can be more effectively rewarded in other ways—through fiscal incentives or preferential purchases by government corporations.

2.53 A further instrument for promoting technological capacity is the use of *mandatory standards*, particularly for materials and components. Mandatory standards can stimulate improvements in the quality of products, especially where they and their associated testing procedures are made progressively more stringent over time. But, again, considerable care needs to be exercised. Standards can easily be used to impose international levels of finish and packaging so as to protect the products of foreign enterprises from competition by local firms which are making genuine innovations, using local materials, and producing at competitive prices.

Tax incentives

2.54 Incentives for technological innovation can be supplied by *fiscal policy*. Concessions and exemptions from both direct and indirect taxation have advantages over other instruments—such as grants or subsidies to particular firms, or state managed R & D—because they minimise bureaucracy, avoid the need for invidious distinctions between firms, are stable and predictable, and reward success. Singapore, for example, has used tax holidays, generous tax deductions and accelerated depreciation allowances to attract substantial investment in high-technology activities. Fiscal incentives, however, have the disadvantage of providing costly benefits to many firms which do not need them. They can be made selective, though for this to be effective needs a capacity for making economically efficient choices. Some governments—such as those of Japan and South Korea—seem to be able to do this, but many do not.

Macro- and micro-economic policy

2.55 General economic policy and performance are undoubtedly crucial to the climate for innovation using new technologies. At a *macro level*, innovation is more likely to occur in conditions of economic expansion. The process is circular. In some countries, such as Japan, and South Korea and the other Asian NICs with rapid growth in exports and domestic sales, new investment pays off rapidly. Rapid expansion feeds favourable expectations among entrepreneurs. The introduction of new technology is frequently profitable and profits finance new investment, more R & D and innovation. Rising consumer spending creates new demands. And as some economies, including the NICs, push against the frontier of full employment, there is a further stimulus to process innovation.

2.56 The opposite case is one of recession and slow growth, especially if accompanied by inflation which blunts the awareness of genuinely viable innovations. These conditions have been experienced to some degree in Western Europe; very acutely in Latin America, where 'adjustment' policies have caused substantial falls in per capita income; and most seriously of all in the prolonged crisis being experienced in sub-Saharan Africa. In each of these contexts one of the consequences of attempts to maintain current living standards has been a cutback in investment. In the most extremely affected countries, especially in sub-Saharan Africa, scientific and technological capabilities are also being cut back drastically in order to given precedence to debt service and to food and energy imports. The position of technological development in many of these countries borders on the desperate, with serious setbacks to research, insufficient services and investment of all kinds. The resolution of the wider economic problems is no part of the remit of this Report, but it needs to be underlined that every effort should be made in conditions of crisis to protect the technological and scientific infrastructure on which long-term growth depends.

2.57 There are also economic policy issues at the *micro level*. Deficiencies in technological development in many developing countries can be explained in large part by distortions in specific labour, capital and foreign exchange markets. For example, overvalued exchange rates not only make exports and import-competing activities unprofitable, but frequently lead to exchange control under which arbitrary decisions to allocate foreign exchange for particular items of high-technology hardware or software can wreak havoc with attempts to create a rational technology policy. Measures to rationalise markets so that prices reflect scarcity can clearly alleviate these problems. A similar remedy can stimulate technological innovation and more intensive use of new technologies in energy and agriculture. The 'green revolution' has progressed fastest where government research, extension and distribution services have been complemented by ample price incentives to farmers as well as by cheap agricultural inputs.

Support for indigenous new technology products

2.58 For countries with a large domestic market, there may be the option of developing a capital goods industry and, in the case of microelectronics technology, of building up a capacity to make computers of various degrees of sophistication, together with the main components used in them. There are implications both for *trade policy* and for *government procurement policies*.

2.59 Historical experience of *trade policy* does not provide a very clear guide. There are convincing examples of countries which, at least

at some stage, made rapid progress economically and technologically behind protective barriers (Japan and Germany), and of others where similar progress took place under free trading conditions (some of the smaller OECD countries; more recently Singapore and Hong Kong). The case for a more protective policy is that it is necessary to build up the local industry and especially the capital goods—machinery—sector needed to secure a firm technological base. It is argued that intense competition could inhibit entrepreneurs from experimenting with new technology. The experience of countries such as India, which broadly have protected domestic production (especially of capital goods), is that they have enabled the economy to build up a diverse and fairly sophisticated base in industrial technologies, including exports of capital goods; but the same set of policies has also fostered areas of inefficiency and technical backwardness. The trend of policy in the light of this experience is towards import liberalisation and in the particular case of electronics, towards freer, albeit selective, import of capital goods and components.

2.60 In the case of electronics some degree of import management is likely to be necessary even within a generally liberal approach to imports of hardware. For example, if a large number of models are admitted, this will impair the country's ability to develop an efficient local software capacity, especially if systems are incompatible. But too small a number will risk giving overseas suppliers a monopoly position.

2.61 *Government procurement policies* can also be crucial in developing indigenous technology. In many sectors, the government usually accounts for most of the domestic market: military equipment; civil aircraft; telecommunications; pharmaceuticals; power plant; some branches of civil construction—roads, railways, ports and airfields. Typically also, governments probably account for more than half of the aggregate market for electronics products. While in some developed countries, procurement—especially of defence equipment—is used consciously as a means of stimulating technical innovation, in many developing countries the reverse may apply. In these countries the availability of 'cheap' equipment under aid programmes, and the greater ability of multinational companies to comply with formal tender requirements and procedures, may induce a bias against domestic firms. This can be combated in various ways:

—governments can give local firms an opportunity to compete for supply contracts on a preferential basis or reserve contracts for them. This gives the local firms a secure market, reduces their risk and creates a learning opportunity;

—the public sector can encourage local firms to achieve international quality and cost standards through the use of component/equipment performance requirements;

—publicly stated procurement policies which favour local firms can be used to alter existing relationships with foreign suppliers of technology, forcing the latter to make more effective technology transfers; and

—governments can insist on a full appraisal of alternative technologies, using a comprehensive social cost-benefit framework rather than narrow commercial criteria. In this way, 'appropriate', if unconventional, technologies can if necessary be brought within the purview of decision-makers.

2.62 It needs to be remembered, however, that the effects of government preference for local suppliers are much the same as those of import controls. There are costs (to public sector consumers and the budget) as well as benefits, and there is a danger of creating uncompetitive, undynamic enterprises dependent on government patronage.

IV. MANAGING TECHNOLOGY FOR SOCIAL NEEDS

2.63 The broad consensus required to mobilise support for economic and social adjustment to accommodate technological change will only occur if the benefits of that change are tangible for most sectors of the population. The benefits of new technologies will be apparent principally in the form of rising living standards. Immediate gains will be felt in the form of new or higher quality products and lower (real) prices for existing products. However, there are important respects in which the commercial innovation of technology, and market adjustment, will fail to meet social needs, even if they satisfy private demand:

—where the majority of the population have low incomes and play little or no role in the money economy, as in many developing countries. The products of new technology, being designed primarily for middle- and high-income consumers, may be irrelevant to their needs (and possible harmful); and

—where new technologies have implications for aspects of life which go well beyond the purely technological and economic: the environment; official secrecy and individual privacy; national security.

Technology for basic needs

2.64 While technology policy cannot, by itself, rectify major inequalities of income and opportunity, governments can try to correct the bias in technological innovation favouring the tastes only of middle- and high-income consumers in developing countries and of consumers in developed countries generally. There are, for example, new technologies

which can be developed, and their diffusion encouraged, which reduce the cost of necessities and the insecurity and drudgery of life of low-income groups. They include those directed towards:

—cheap energy for rural households and small farms being developed through biogas and, on a smaller scale, windmills and solar power;

—drought- and pest-resistant, high-yielding, strains of foodgrains, especially those such as cassava, which are indigenous to low-income countries;

—improved health services making use of new vaccines and drugs developed through advances in biotechnology and of micro-computers for survey work, clerical tasks and management purposes. China is reportedly far advanced in combining indigenous low-technology with sophisticated imported technology;

—television-based mass literacy campaigns, combined with informal education, as are being carried out in India;

—low-cost construction, water supply and sewage disposal techniques;

—remote-sensing to evaluate water resources;

—improved low-cost transportation (bullock carts, cycle rickshaws) and cheap all-weather, feeder, road construction for rural areas; and

—disaster warning systems based on satellite detection.

The above list is merely illustrative. It might be expanded to include items which, while not specifically used by low-income groups, are important basic services: for example, using advanced communication systems to develop an efficient telephone service.

Technology assessment and wider social impacts

2.65 There is a high degree of consensus that technology should be evaluated and managed according to wider criteria than those of technologists and economists. Among the other criteria is the *environmental* impact.

2.66 We have seen how new technologies can assist in environmental protection and ecological conservation; the use of biotechnology to maintain a better genetic balance in forest, animal and plant life, to recycle waste, and develop forms of agriculture which make less use of land; the development of new energy technologies which reduce dependence on fossil fuels and nuclear power; the application of satellite tracking to monitor forest depletion, land erosion, and over-use of water supplies. But there are also dangers to the environment, to the

air and water from pollutants and to the land from the application of new chemicals (for example long-term consequences of excessive nutrients in conjunction with high-yielding seeds).

2.67 Among the many ways in which governments can act to minimise any deleterious side-effects of new technologies on the environment are:

—to enact and enforce national and international legislation regarding environmental pollution. In particular action is necessary to control the use of modern technologies where there is a danger of serious damage to ecological systems beyond the immediate area of application (for example, acid rain, fluorocarbons);

—to enact and enforce policies relating to natural resource conservation, particularly forests;

—to make efforts to substitute non-renewable resources, both minerals and energy, by renewable ones and to conserve the rate of consumption of selected non-renewable resources; and

—to enact the necessary legislative and other administrative mechanisms to promote the culture of recycling and utilisation of 'waste' materials of all kinds. In some cases, notably the disposal of nuclear waste, new legislation may be required.

2.68 Another element in technology assessment would have to be the *health and safety* impact. A new generation of products and processes is emerging whose properties and long-term consequences are very imperfectly understood. The ramifications are immense, but two policy priorities should be stressed. There should be:

—greater research and monitoring by independent bodies of the side-effects and control of potentially dangerous substances and processes. This is especially true of the new biotechnologies where barriers to entry are often low, but where there is emerging a higher degree of secrecy and limitations on access to property information; and

—creation of at least a minimum 'critical mass' of health, safety and consumer protection officials, particularly in developing countries, independent of both the corporate sector and those sections of government with an interest in promoting new technology.

2.69 Yet another area of concern is the way in which the revolution in information processing can be abused to encroach upon *privacy*. The problem is complex and involves preventing the invasion of individual privacy by control and surveillance techniques which are still evolving, while also granting individuals' access to official information stored in a large and growing number of ways. Agreement is needed,

both nationally and internationally, to define the basic principles for data protection, including transborder data flows, and enact appropriate legislation to ratify the agreements reached. Many governments have already passed legislation but more should consider doing so, while there is also need for greater harmonisation between the various national laws enacted.

2.70 Numerous other ethical, social or political problems are being presented by new technologies: the potential beneficial and malign consequences of genetic engineering and embryo research; the military possibilities for governments, and terrorists, of 'intermediate technology' entering the fields of germ warfare and nuclear weapons. Where public policy can improve upon idle speculation is to support serious technological forecasting and research into the impacts of new technologies.

V. MANAGING ADJUSTMENT TO TECHNOLOGICAL CHANGE

2.71 The concept of adjustment is not new. Since the industrial revolution there has been a continuous process of adjustment to technological change, manifested primarily in the movement of people from the agricultural sector to industry and from a rural to an urban environment. Such adjustment is both a consequence of economic growth and a precondition for it.

2.72 The analysis of the impact of technological change in Chapter 1 pointed to several reasons why it is now necessary to devise policies to assist the process of adjustment:

—there has been a growing awareness in developed countries, especially in Western Europe, that the recent slowdown in economic growth is associated with major 'structural' weaknesses, including reduced job mobility and a slackening pace of technological innovation. A broad consensus has emerged that 'positive adjustment policies' should be adopted;

—technological change, even if beneficial for the majority, may create hardship for particular groups: for example, displaced workers and those living in the neighbourhood of polluting plants. Such an inequitable distribution of costs and benefits needs ameliorative action if technology is to be generally welcomed rather than resisted; and

—the ease of adjustment in one country has implications for others. For example, the growth of protectionism in developed countries,

which is a symptom of lack of adjustment, creates serious problems for exporters elsewhere, particularly in developing countries.

Economy-wide policies

2.73 A crucial area influencing the speed and ease of adjustment to technological change is the general conduct of economic policy. Such policy can be designed to engender flexibility and encourage workers and businesspeople to take a stable, long-term, view of their working lives and investments, so that the short-term costs of technological adjustment do not loom overwhelmingly large. There has been a great deal of analysis by the OECD (of developed countries) and by the World Bank (of developing countries) of the economic policies which are most conducive to technological and other adjustment, and we shall here merely summarise their conclusions.

2.74 In the field of *macro-economic* management, price stability, high employment, steady expansion of demand and external equilibrium favour smooth adjustment. By contrast, inflation reduces the capacity and willingness of businesses to invest, restructure and innovate; insecurity created by high unemployment acts as a spur to resist change; and balance of payments crises add uncertainty and instability. But there is a two way relationship between macro-economic and *micro-economic* policies which make use of market incentives. The former will not work satisfactorily without a willingness to change at the micro level by all concerned: for example, labour mobility and a readiness to adapt at the workplace; a willingness by businesspeople to take risks and invest; and competitive markets for goods and services. Yet micro-economic flexibility will often be resisted in adverse macro-economic conditions. Thus there frequently occurs a virtuous circle of flexibility and economic stability or a vicious circle of rigidity and economic instability.

Education policies and adjustment assistance

2.75 A good deal of technological adjustment takes place within enterprises (including those in the public sector) and rests on a framework of dialogue and consent between managers and workers. But much also takes place as a result of changes in patterns of demand and competitive pressures over which an individual firm has little control; so whatever progress can be made in negotiating adjustment to new technology, there is also need for acceptance of wider structural change. Experience, especially in developed countries, has pointed to the importance of the following:

—*school education*. The experience of developed countries has increasingly pointed to the need not only for specific vocational training but also for a broader approach to education—drawing

heavily on mathematics, natural science and technology—which lays the foundation for adapting to changing and more sophisticated skill requirements later in life;

—*continuing education*. This is a broader approach to retraining than the narrowly vocational. Its underlining principle is the idea that adults (as well as children) have a right to enjoy further education at stages throughout their career, so as to adapt to future scientific-technical demands;

—*retraining* (and initial training for youth). This is crucial to facilitate technological adjustment at a time of rapid technological change. It calls for substantial and increasing resources from the public sector and incentives for the private sector. Retraining for older workers has however proved to be full of practical difficulties in the absence of an integrated approach involving counselling redundant workers and specially targeted schemes to assisted re-employment;

—*employment programmes*. There is an important role for these programmes specifically targeted to groups such as youth, women and other disadvantaged groups who are considered at particular risk from technologically-induced unemployment (for example, in low-skill activities which are easily replaced by microprocessor applications);

—*redundancy payments*. These can cushion the impact of change on individual workers. In order not to slowdown mobility or discourage investment, redundancy payments can be restructured: first, by society as a whole, rather than employers, accepting part at least of the costs of structural change (in the form of retraining and redundancy payments); and second, by refashioning redundancy payments to act as an incentive for re-employment elsewhere (including self-employment); and

—*pension and housing entitlements*. Pension entitlements are often so rigidly administered as to be a serious barrier to mobility between occupations. They can be made adaptable through comprehensive state, or portable private, pension schemes. Similarly, housing difficulties prevent geographical mobility. This problem can be eased through relocation expenses for displaced workers and greater transferability of entitlements among local authorities.

Most of these policies, however, imply costs for governments, and most developing countries, which lack the resources for comprehensive welfare state provision, are unlikely to be able to provide other than modest adjustment assistance.

Regional policies

2.76 The costs and benefits of new technologies are rarely spread evenly in geographical terms. The growth of electronics-based industries in developed countries has been so far centred on areas where there are concentrations of qualified manpower and satisfactory infrastructure. Similarly the major breakthroughs in developing country foodgrain production based on new technologies has been very unevenly spread. And decline is equally concentrated—in areas of developed countries with traditional labour-intensive industries, such as textiles, or rapidly automating industries, such as vehicles; or in developing countries where technology has reduced the demand for specific commodities. There is now considerable experience, particularly in developed countries, of measures which can mitigate regional decline and disparities in development. Arising from this is a broad consensus that two of the most effective measures in the long term are the provision of *infrastructure* and of *fiscal incentives* which are differentiated regionally.

Labour relations and conditions of work

2.77 A satisfactory system of labour relations, with decisions based on consultation and, where possible, on consensus, will increase the acceptability and, consequently, the speed of technological change. In many cases difficulties which arise in applying new technology can be resolved locally by decentralised bargaining between workers' representatives and employers. Where, for example, new technologies involve the design of new systems of work organisation, participation by employees in the design process is frequently found to be of mutual benefit to employers and workers. Such an approach is inadequate, however, insofar as many of the consequences of technological change occur not as a result of specific actions by the employers of the workers directly affected, but as a result of changes in other enterprises producing competing or complementary goods or services. For this and other reasons, including instances where the government itself is the employer introducing technological change, wider issues of public policy arise.

2.78 As a general rule there should be the earliest possible process of consultation between those implementing the technological changes and those affected by them. This process would not only facilitate the provision of information on the opportunities offered by, and the problems associated with, new technologies, but it would provide a basis for consensus on how the changes should be implemented. Such consultations should involve all those affected: trade unions, where these represent organised workers, together with other relevant groups, such as peasant farmers' cooperatives and consumers' organisations, as well as employers. Governments, too, may well be part of the consultative process. The objective would be to create a climate conducive to decision-making based on a consultative approach to the

introduction of new technologies. Such an approach is contained in the ILO's recommendations concerning employment policy, which we reproduce elsewhere in this Report (see Volume II, Appendix 7).

2.79 The great diversity between countries and technologies makes it very difficult to progress from abstract generalities to policy outlines, but a few approaches can be suggested:

—one is to strive for general recognition of the rights of workers to organise to represent their interests, leaving the details of negotiating technological change to specific local circumstances. This approach is primarily relevant to organised wage and salaried employment. Where, as in many developing countries, this accounts for only a small proportion of the working population, additional mechanisms are needed. Ultimately, in some developing countries, the provision of at least minimum rights for workers will depend primarily on governments;

—a complementary approach is to have recourse to generally recognised international norms such as those embodied in the ILO labour statutes. These provide a basis for legal and moral pressure where employers are cavalier in their regard for working conditions; and

—a more novel concept, being pioneered in several countries, is to adopt 'new technology agreements' at the level of the plant, enterprise or industry. Such agreements have been deployed in countries which have made marked technological and economic progress, assisted by good labour relations, but which have been concerned over technologically-induced unemployment. Some of the features of these agreements are likely to find broad acceptance—in particular those relating to training and retraining, and health and safety. We reproduce elsewhere in our Report some possible ingredients of such agreements (see Volume II, Appendix 8).

Adjustment policies of particular concern to developing countries

2.80 Many of the above measures arise largely from the problems of adjustment in developed countries. By contrast, the same problems may often be seen as opportunities in developing countries. For example, the 'deskilling' aspects of some new technologies may make it easier to introduce more efficient processes, hitherto impeded by skill bottlenecks. And any reduction in the demand for female labour in urban offices is likely to be seen as outweighed by the need to use new technologies to alleviate the drudgery of women in a rural environment whose life currently revolves around child-bearing, wood collection for fuel, water carrying, and low-productivity subsistence farming. Nonetheless, there

are respects in which new technologies present developing countries with problems of adjustment which require a policy response.

Adapting technological processes

2.81 There are well established, indigenous, labour-intensive technologies which face competition from mechanised technologies. The classic case historically has been the replacement in Asia, especially India, of hand-woven textiles by factory-made cloth.

2.82 Emerging technologies could have a similar effect, demolishing traditional occupations at great social cost. But they could coexist with traditional technologies in a complementary fashion. The benefits of such an integration, or 'blending', are that existing production methods, and employment, can be preserved, possibly with enhanced efficiency. Technology 'blends' are more likely to be assimilated, developed and improved, than are wholly alien, large-scale and capital-intensive technologies. Examples which have been demonstrated, at least on an experimental basis, are the use of microprocessors to provide control functions in biogas production (raising productivity in terms of biomass by a factor of five); in testing and quality control for small dairy farmers (thereby reducing waste); and in control devices in the highly decentralised Italian textile industry, to reduce faults and waste, together with telematics to coordinate outworkers.[3] There are many other possible uses of new technologies in conjunction with traditional activities: micro-computers in agricultural planning; high-yielding seeds in subsistence farming; remote-sensing for water exploration; satellite communications for education in villages. There are, of course, technological limitations on 'blending', and problems of assembling the software services required to make it cost effective. Nonetheless governments can play a useful catalytic role in promoting or undertaking:

—R & D, based on a thorough understanding of traditional as well as emerging technologies;

—centralised training and software services for 'blending' schemes; and

—trial and demonstration projects to encourage adoption by small-scale users.

Product development

2.83 Special diversification programmes can assist countries, or regions within countries, to cope with the decline of activities on which they are almost wholly dependent. New technology is not necessarily inimical to commodity exporting in general, but adjustment problems will arise.

In part, these will have to be met through general economic policies centering on producer incentives; but such incentives may be slow acting in highly specialised economies. Supplementary adjustment measures could include the following:

—joint action by producers (and consumers) to devise early warning indicators of future adjustment problems, to estimate future market demand and to plan accordingly;

—R & D and other assistance to develop new products from the same raw materials (for example fuel alcohol from sugar cane; producer gas from sugar fibre; livestock feed from cane by-products);

—support for the use of new technology processes which improve the yields of existing raw material production costs by, say, reducing wastes (for example bacterial leaching of copper wastes);

—joint ventures with firms from developed countries in production of substitute products; and

—research, advice, credit and marketing support for alternative crops which are agronomically appropriate and economically attractive.

2.84 There are grounds for believing that the broad thrust of new technologies is towards greater economy in raw materials use and, thus, to a general weakening in the market position of commodity exporters. But the position is not universally discouraging. New technologies have the potential to improve the quality of traditional products (for example blending man-made and cotton fibres), or make them cheaper (as in the use of microprocessors to economise on energy inputs), or create new sources of demand (as in Malaysia where it is hoped that current genetic experiments will lead to foreign exchange savings by enabling palm oil to replace diesel fuel).

Manufactured exports and trade policy

2.85 If developing countries diversify their exports from commodities into manufactures they face problems of technological adjustment of a different kind—the advance of labour-saving technologies into those product areas in which low labour costs have been a source of comparative advantage. This raises the question as to whether developing countries should now redefine their trade policies in the light of greater export pessimism.

2.86 Hitherto pessimism has been confounded. The export-oriented NICs have consistently outperformed other developing countries with comparable resources, both in respect of export growth and overall economic performance. While the experience of the NICs is impressive,

doubts exist as to whether it can be extrapolated forward to less favourable international conditions which include a combination of slower growth and protectionism in developed countries, as well as the impact of new technologies.

2.87 As far as the NICs themselves are concerned, and the more advanced of the second tier of countries exporting manufactures, there are no strong reasons for doubting the continuing validity of the broad trade strategy they have adopted, provided that—as countries such as South Korea and Singapore recognise—their areas of comparative advantage are viewed dynamically to reflect a growing scarcity of unskilled labour and a rising technological competence and marketing sophistication. There is already evidence that the NICs are successfully diversifying their exports into goods and services by making greater use of skilled labour, and advanced technology.

2.88 A larger question mark hangs over those countries—particularly the low-income developing countries—which are still, predominantly, commodity exporters. When they seek to diversify they face the prospect of being shut out of markets in developed countries by a combination of protectionist barriers and the diffusion of automation in traditional labour-intensive manufactures. So far, at least, these fears have proved exaggerated. Protectionism is a serious problem but is not prohibitive. In such an important sector as clothing—as we discussed in Chapter 1—the diffusion of automation technology has not widely penetrated such processes as sewing and does not yet threaten countries which have a competitive advantage based on the mastery of conventional technologies. Moreover, the market continues to throw up a demand for new products which low-income countries, with low labour costs, are ideally placed to supply; products with individual styling (such as the 'cabbage patch' doll) or complex hand-manufactured operations (the success of Indian handicrafts and cut diamonds, for example); labour-intensive activities which are becoming internationally traded with improved communications technology (printing; knock-down furniture manufacture; software services). And factories using relatively labour-intensive processes also have the advantage of being able to respond more quickly to a sudden increase in demand than do those using much equipment which takes a long time to build, test and commission. If we are to take a long-term view, it seems likely that the growing use by producers in developed countries of automated production methods—and eventually flexible manufacturing systems—will preclude developing countries from building up a comparative advantage in many areas of manufacturing where this could have been expected on the basis of current technologies. But, by the same token, there is every reason for speeding the removal of protectionist barriers in developed countries which exist to defend their industries against 'low-cost' suppliers.

VI. MANAGING IMPORTS OF TECHNOLOGY

2.89 For many developing countries and for most of the smaller developed countries, there will remain a high level of dependence on imported technology. The import of technology, however, can be managed in ways which make it consistent with the objective of developing an indigenous capacity. Government can play a role in this process in several ways:

—the development of an indigenous capacity to adapt new technologies will often necessitate action to ensure that there is a genuine transfer of technology along with hardware and proper attention to the 'systems' implications of imported hardware. This action can include obligations on importers of technological hardware to train nationals, not only to operate equipment but to adapt it, to use local engineering consultants, and in these and other ways to transfer the technology embodied in the machinery; i.e. the 'know-why' as well as the 'know-how';

—it may be necessary to assist domestic purchasers to gain access to the best and most appropriate international technology in a world where there are major gaps in information and many deliberate restrictions on the transfer of technology; and

—where there are small numbers of powerful suppliers and limitations on competition because of the complexity and scale of new technologies, governments in technology-importing countries may need to intervene to improve the terms of technology transfer, both quantitatively (such as prices or royalties) and qualitatively (including the removal of restrictive clauses).

2.90 The international market for technology is complex and imperfect. In general the greater the technological capacity of the importing country the better placed it is likely to be in handling each stage of the technology transfer. There are, in addition, several ways of importing technology which work better in some countries than in others, not least because of the different demands they make on indigenous capacity. Managing technology imports requires making an optimum choice among the options available.

Direct purchase or acquisition

2.91 Much technological know-how is free, or at least freely available in numerous technical and trade journals and manuals, as well as amongst lapsed patents and unpatented inventions. Attempting to acquire technology in this manner may not, however, be an appropriate strategy for poor or very small countries. They often lack the technical and managerial capacity and skilled labour to know where to look for

appropriate technologies and how to assess which to buy, let alone use and assimilate. Nor may such a strategy give access to the latest technologies.

2.92 Many owners of new technology are reluctant to sell to potential competitors and thus risk a 'boomerang effect'. But there are exceptions and, in the electronics industry, some enterprises in developing countries have been able to obtain much of their technology royalty-free from component manufacturers, machinery makers and materials suppliers, while some producers of consumer electronics goods have been given the necessary technologies by United States mass-merchandisers seeking to lower their retail prices. Even so, this is an option of limited application which requires a strong base in information collection and other supporting infrastructure.

Purchase of imported hardware

2.93 Technology is embodied in machines and will usually be imported in this form. But a frequent consequence of importing hardware without attention to technology transfer is that there is insufficient associated training and software. Recipient firms get the hardware and some operator training but rarely acquire the underlying know-how and expertise required to improve and adapt the imported techniques. In rare cases (Japan is a good example), a machine or system may be imported once, mastered and thereafter maintained, adapted and replicated domestically. In some other cases, technology is transferred not just in the machinery but also in the setting-up and initial training and management, after which local technological capacity develops enough to continue operations. But more frequently, where technological capacity is limited, machinery is acquired with a continuing dependence on foreign suppliers for operating and maintenance assistance.

2.94 As a result, the performance of imported plants and machines in developing countries often declines over time, whereas that in developed countries normally increases. By striving to maximise the learning component of technology transfer, developing countries have opportunities to develop the capability not only to improve the efficiency of existing plants, but to participate in design and engineering, in the local fabrication of plant and equipment, and often, particularly in the case of the poorer countries, in the development of managerial capabilities.

2.95 In policy terms, this means that governments in importing countries need to develop a capacity to evaluate technology imports, making them conditional upon a training element to provide 'software' and 'systems', and ensuring that technology is 'appropriate' in terms

of its technical and economic characteristics. Aid donors also have a responsibility to ensure that any equipment purchased under aid projects is appropriate to local conditions, and is accompanied by technical assistance for project implementation and training where necessary.

2.96 A particular application of the need for a thorough appraisal of technology imports is in the field of computers, particularly micro-computers. There are many pressures leading to their wider use in developing countries. Suppliers of micro-computer hardware and software are actively searching for markets. IBM, for instance, has created an African institute to foster the use of micro-computers as a tool for development. International and bilateral agencies often play a key role in encouraging aid recipients to use computers. Internally, a growing array of government departments are pursuing new technology to create (as they see it) more effective administration, planning and project implementation.

2.97 Given these pressures and potentials, together with the key role of government as a consumer, it is only logical that policies should be developed to guide the introduction and use of imported micro-computers. These policies must start by recognising that the operating environment for micro-computers in developing countries differs greatly from that in the developed countries. In the latter, there is usually a high degree of competence among systems users, local production of hardware and software, available technical support and maintenance, software programmes written in the national language of the user, etc. In developing countries, particularly the poorer among them, almost the opposite prevails. The potential user will be inexperienced, existing programmes of data collection and processing may be inefficient, and decision-making may be highly centralised. In addition the technical environment may be unsuitable: there are often unstable electricity supplies, poor quality transmission lines and climatic factors which can adversely affect the functioning of a computer. Consequently there are numerous examples where micro- and other computers have been introduced into an unsuitable environment and never used properly. However, there have also been major successes, such as the introduction of a network of micro-computers into the Egyptian Health Authority. The successes and failures alike suggest that one of the most important steps is a careful evaluation of the system into which imported technology is to be accommodated—preferably by specialists familiar with the country, rather than by salesmen of the hardware suppliers, as is often the case.

2.98 One of the options to be considered where there is concern to avoid importing 'inappropriate' technology is to import *technology from other developing countries*. Several countries—India, Brazil,

Argentina, South Korea, China (Taiwan) and Mexico—have begun to export equipment, turnkey plants and engineering consultancy services; India, for example, exports sugar processing and cement equipment, machine tools and major construction complexes. Technology imported from these countries often has the advantage of being derived from a learning and adaptation process suitable to developing country conditions. One of the dangers of acquiring and mastering less sophisticated and apparently 'appropriate' technology, however, is that in the long run it may be more costly than advanced technology. Thus those developing countries which are learning to operate, adapt and replicate, say, electro-mechanical telephone systems now find that these have been superseded by cheaper and more efficient digital networks.

Foreign investment

2.99 Subsidiaries of TNCs are among the principal agents of technological transfer to developing countries. Many developing countries have liberal policies towards foreign investment based, in part at least, on the access which that investment gives to foreign technology, not only hardware but accompanying 'software'. Others are more selective, encouraging investment only where it is considered indispensable for technology transfer—as in the case of India. Foreign investors are seen as transferring technology directly to their subsidiaries or indirectly in various ways: through backward linkages with local suppliers; by making demands on local firms for enhanced skills to provide maintenance and repair facilities; and by competition with local firms, so compelling the latter to upgrade their skills and standards.

2.100 This particular mode of technology transfer—direct investment—has several attractions: the transfer is usually relatively fast; foreign investment reduces the need for investment in indigenous R & D; the multinational companies have an incentive to ensure that their technology is properly utilised and, where necessary, adapted; and the technological and financial risks fall on the company and not the country. In general these advantages will be perceived more readily in countries at the early stages of industrialisation, when benefits can be derived from mechanisms which combine, in one package, technology with capital, skills, marketing and management. For countries with a greater technological capacity, a more selective 'depackaging'—acquiring the technology in isolation—may have greater attractions, though it is perhaps significant that foreign investment is still a favoured mechanism for sophisticated NICs such as Singapore, and also for countries in Western Europe in relation to US technology. While this is not the place to rehearse the arguments and counter arguments, it suffices to say that some governments have a less positive approach to foreign investment, based on a variety of considerations. These include:

the limitations on technology transfer embodied in many contractual arrangements involving TNCs and their subsidiaries (such as tied purchases or imports; restrictions on imports which threaten the company's other activities; a dependence on expatriates); the perceived inappropriateness of technologies and products; and the disincentive to local innovation when multinationals see their subsidiaries as providing a captive market for obsolete technologies and goods. Suffice it to say that foreign investment may be an invaluable source of transferred technology but by itself will not transfer technology. It is for the government of host countries to ensure, through incentives or restrictions, that training, local R & D, and technology adaptation do take place.

Alternative forms of collaboration with multinational companies

2.101 The costs and benefits of foreign investment can, however, only be meaningfully evaluated when set alongside other feasible options for acquiring technology from multinational companies. Another method for obtaining such technology is *licensing* or some form of *technical cooperation* agreement. The Japanese successfully used the licensing system in the 1960s to import technologies and develop indigenous capabilities without recourse to direct foreign investment. A 'staggered entry' approach was used, permitting one domestic firm at a time to acquire and absorb licensed technology. Other countries, notably India, South Korea and several in Latin America, have also attempted to make use of licensing for technology transfer. But the process of screening and evaluating licensing agreements can have the effect of greatly slowing down the rate of absorption of technology, as appears to be the case in India relative to—say—Brazil, Mexico, China (Taiwan) and South Korea. Moreover, licensing raises the same problems as mentioned above for straight purchasing, namely requiring local expertise as well as financial resources, while it may not provide access to the newer technologies. Studies on Latin America, for example, have found that the use of pure licensing is positively correlated with the maturity of the industry and inversely with patent protection. Direct equity investment, on the other hand, is a more attractive vehicle where complex technologies are involved; and for countries without the resources to negotiate superior alternative arrangements.

2.102 Joint ventures, in which foreign companies help local enterprises to set up production through minority shareholding, are being actively promoted by a number of developing country governments. The latter aim, thereby, to achieve technology transfer from a foreign investor and access to foreign markets without losing indigenous control. Many governments are unsuccessful in this aim, since the foreign companies exercise control despite their minority shareholding. Most successful

joint ventures appear to have been restricted to industries producing for the domestic market rather than for export, or in mature industries (textiles, industrial chemicals, non-ferrous metals) rather than in newer ones (computers, pharmaceuticals, etc.). Moreover, there is less likelihood of an effective technology transfer being made than with wholly or majority owned subsidiaries. The proportion of technologies transferred to majority owned affiliates which were 'new' (i.e. less than five years old) rose from 25 per cent in the 1960s to 75 per cent in the 1970s for a sample of chemical, semiconductor and pharmaceutical industries. And according to a survey by ESCAP, the average age of all technologies transferred by multinational companies under joint ventures and licensing was 13 years, while for subsidiaries it was five to eight years. Nonetheless, the joint venture route is being increasingly explored in the Asian NICs. For example, leading South Korean companies are developing technologies, in genetic engineering, fibre-optics, and computer controls, on a joint venture basis with US companies. And in Malaysia a leading plantation company recently teamed up with a leading US biotechnology company to carry out plant genetic engineering in the ASEAN region.

Importing 'know-how' directly

2.103 We have referred above to various modes of technology import which can incorporate training and management (such as foreign investment), and also to other imports (such as machinery) which relate specifically to 'hardware' aspects of technology. For countries which lack the trained people, it may be necessary to import them, if not along with the hardware, then independently. The lower the level of indigenous capacity and the smaller the country, the more likely this is to be necessary. Trained people can be imported through:

—*consultancies*. The use of foreign consultancies in, say, systems design and other technology-intensive activities may be a necessary first step to acquire a domestic capacity. But it would need to be allied to measures to raise local consultancy capability by, *inter alia*, gradually increasing the share of public contract work given to local consultants and the share of project work under aid programmes;

—*management and service contracts*. Where new technology 'hardware' requires complex establishment, operating and maintenance skills, a first step may be to hire management and other skills. The experience with such arrangements, however, is that they are likely to be self-defeating as a mechanism of technology transfer unless remuneration is based on a sliding scale in relation to performance and there is a clear timetable for counterpart training and the gradual phasing-in of local management;

—*education and training abroad.* We have referred earlier to the role which might need to be played by education and training abroad where local facilities are deficient. Consideration needs to be given to solving the well-known problems of: inappropriate specialisation; defective selection; the 'brain-drain' when overseas stays are too long; and the limited communication of education or skills when the stays are too short; and

—*technical assistance.* Aid donors can provide experts at below market rates to perform operational, training or advisory roles incorporating technology transfer. The advantages and pitfalls of technical assistance are too well-known to need rehearsal here, but for countries which require not only imported hardware but the skilled workers to use and adapt it, and lack the resources to buy these skills commercially, technical assistance is indispensable.

2.104 Thus, while indigenous development of the 'software' aspects of new technologies may be the best point of entry for countries to master new technologies, a 'software' capability may itself have to be imported in the first instance, requiring systematic evaluation of the various options.

NOTES*

1. UN, *Study on the long-term plan of action for the establishment of the global information network*, New York: 1985, A/CN. 11/56.
2. For example, M. Ul Haq, 'Wasted Investment in Scientific Resarch', in W. Morehouse, ed., *Science and the Human Condition in India and Pakistan*, New York: Rockefeller University Press, 1968; D. James, 'Scientific and Technological R & D in Developing Countries', in J. Street and D. James, eds., *Technological Progress in Latin America: The Prospects for Overcoming Dependency*, Boulder, Colorado: Westview Press, 1979; and N. Girvan, ed., Science and Technology Policy in the Caribbean, *Social and Economic Studies*, Vol. 28, No. 1, Institute of Social and Economic Research, University of West Indies, Jamaica: 1979.
3. A detailed survey is to be found in James (1984).

* Complete references to the works cited are given in Volume II, Appendix 10, Selected Bibliography.

TABLE 2.1
Characteristics Related to Technological Capacity in Selected Countries

	Categories/ Countries	Population (millions) mid-1983	GNP		
			Total at market prices (mn. US $) 1983	Growth rate (per cent) 1973–82	Per capita US $ 1983
		(1)	(2)	(3)	(4)
I	*Major developed economies*				
	United States	234.5	3,292,340	2.5	14,110
	Japan	119.3	1,204,270	4.3	10,120
	United Kingdom	56.3	505,610	0.9	9,200
	Germany, F.R.	61.4	702,440	2.3	11,430
II	*Medium or small, open developed economies*				
	Canada	24.9	300,400	2.3	12,310
	Australia	15.4	166,230	2.3	11,490
	Sweden**	8.3	103,240	1.1	12,470
	New Zealand	3.2	24,000	0.4	7,730
III	*Newly industrialising outward-looking countries*				
	Hong Kong	5.3	31,900	9.5	6,000
	Korea, South	40.0	80,310	7.2	2,010
	Malaysia†	14.9	27,760	7.4	1,860
	Singapore	2.5	16,560	7.9	6,620
IV	*Populous developing countries with substantial technology base*				
	Mexico	75.0	168,070	6.2	2,240
	India**	733.2	190,710	4.1	260
	China**	1,019.1	301,840	5.7	300
	Brazil	129.7	245,590	5.2	1,880
V	*Low-income countries with limited technology base*				
	Ghana	12.8	3,980	−1.1	310
	Kenya	18.9	6,450	5.0	340
	Sri Lanka	15.4	5,140	4.9	330
	Tanzania	20.8	4,880	3.4	240
	Bangladesh	95.5	12,530	5.7	130
	Nigeria	93.6	71,030	2.0	770
VI	*Small, open developing countries with limited technology base*				
	Jamaica	2.3	2,940	−2.6	1,300
	Mauritius	0.9	1,250	3.9	1,150
	Seychelles	0.07	160	5.1	2,400
	St. Kitts	0.05	40	1.9	820
	Fiji	0.70	1,190	3.1	1,790
	Trinidad & Tobago	1.1	7,870	5.6	6,850
	Tuvalu	0.008	5[a]	n.a.	680[l]
	Samoa, Western	0.16	140[b]	n.a.	870[b]

MRE: Most recent estimate (see facing page for the years concerned).
n.a. Not available.
* Data in columns 5 to 9 exclude law, humanities and education.
** Excluding social sciences and humanities.
† Data refer to peninsular Malaysia only.
‡ Estimates in columns (6) and (8) correspond to the periods indicated in columns (5) and (7) respectively.

Number of scientists and engineers		Number of scientists and engineers in research and development		Research and development expenditure as a % of GNP	Patents in force 1982
Total	As a % of total labour force‡	Total	As a % of total labour force		
MRE					
(5)	(6)	(7)	(8)	(9)	(10)
3,167,000[a]	2.99	660,700[a]	0.62	2.35	1,199,526
4,127,200[a]	6.76	463,062[a]	0.76	2.41	404,293
n.a.	—	86,500[b]	0.33	2.25	228,067
1,981,000[c]	6.73	121,978[c]	0.41	2.40	136,723
537,925[d]	6.28	28,700[a]	0.27	1.24	413,639
231,705[e]	3.98	22,510[e]	0.39	0.72	48,842
335,900[c]	9.21	14,766[c]	0.40	1.88	48,803
47,249[d]	4.31	8,080[c]	0.65	0.85	n.a.
83,200[a]	3.29	n.a.	—	—	n.a.
1,186,416[g]	8.07	20,718[b]	0.15	0.64	8,346
35,415[h]	0.97	n.a.	—	—	n.a.
38,259[g]	4.01	461[b]	0.05	0.15	8,707
n.a.	n.a.	5,896[j]	0.04	0.23[j]	36,659
697,600[f]	0.27	56,527[b]	0.02	0.53	11,992[a]
5,296,000[g]	1.14	n.a.	—	—	n.a.
541,328[h]	1.80	24,015[b]	0.06	0.56	10,953 [c]
6,897[h]	0.21	4,084[e]	0.11	—	922
5,130[j]	0.10	361[j]	0.01	—	1,607
7,457[i]	0.18	604[f]	0.01	0.14	753
n.a.	—	n.a.	—	—	2,079[g]
23,500[k]	0.09	n.a.	—	—	1,071[g]
19,885[h]	0.09	2,200[f]	0.01	0.32	359[j]
5,963[h]	0.95	n.a.	—	—	1,058[c]
6,264[i]	2.44	152[g]	0.04	0.44	189
300[a]	1.03	2[a]	0.01	0.11	44
135[h]	1.04	n.a.	—	—	n.a.
9,734[e]	5.41	n.a.	—	—	14[a]
3,314[h]	0.98	n.a.	—	—	1,900[j]
n.a.	—	n.a.	—	—	n.a.
350[f]	0.92	140[b]	0.37	—	13[a]

[a] 1981; [b] 1978; [c] 1979; [d] 1971; [e] 1976; [f] 1977; [g] 1980; [h] 1970; [i] 1972; [j] 1975; [k] 1973; [l] 1982.

Sources: World Bank, *World Development Report,* 1985; World Bank, *Atlas,* 1985; United Nations, *Statistical Yearbook,* 1982; UNESCO, *Statistical Yearbook,* 1983.

Chapter 3

International Cooperation in Technology and the Role of the Commonwealth

I. INTRODUCTION

3.2 We have hitherto discussed policy questions primarily in terms of individual countries. However, such is the extent of internationalisation of the world economy that the policies of individual countries, especially large states, and of transnational corporations have implications for policies being pursued elsewhere. This calls for a broader, multilateral, perspective for technology management.

3.2 Cooperation in technology occurs between developed and developing countries ('North-South') and among developing countries ('South-South') and developed countries ('North-North'). It takes a multiplicity of forms—bilateral and multilateral, concessional and commercial. While there are obvious reasons why developing countries should seek support from developed countries in improving their capacity to manage technological change, there are also strong arguments favouring technical and economic cooperation among themselves. We place considerable stress on such 'South-South' cooperation, starting perhaps on a regional basis, and fully support the efforts of the United Nations and other institutions to promote it. But we also recognise that there are major constraints to be overcome—attitudinal, institutional and financial. The strength of traditional trading and investment patterns is such that many developing countries do not utilise technology from other developing countries, while the institutional framework is often unable to support such efforts, and finance is insufficient.

3.3 There are several areas in particular which call for a multilateral approach:

—where national policies spill over and, if only inadvertently, influence other countries. For example, if one country offers tax incentives on high-tech industries with the aim of upgrading its technological base, this may attract footloose companies from elsewhere, precipitating competition in investment incentives. Even where the spill-over effects of national actions are positive—as, for instance, with a decision by a government in one country to promote adjustment of its industrial base up the technological ladder, which leads to other countries gaining its 'cast-off' low-tech industries—cooperation may still help to maximise the benefits;

—where there are large and increasing economies of scale in R & D. Even in countries with relatively large, mature economies, such as the EEC, there have been several programmes of joint activity (in this case Esprit, the $1.5 billion five-year research programme on information technology) in a attempt to keep pace with the technological leaders—the USA and Japan.[1] There are also cases of high fixed costs in the use of new technologies (as in telecommunications) which make their adoption too expensive for smaller economies except on a joint basis; and

—where countries acquire their technology externally, the terms of technology acquisition may be improved by joint negotiations with foreign suppliers, often transnational corporations. Individual governments may find that their attempts to identify new technologies, let alone to control the terms on which they are acquired, are frustrated by their lack of technological information and evaluation capacity and by their weak economic strength relative to the large technology-producing companies or countries. Concern over the inequitable nature of current technology transfer mechanisms has led to strong demands from developing countries for a framework of multilateral cooperation to cover the terms of technology acquisition.

3.4 In this chapter we first consider existing forms of international cooperation, and how they might be improved, with particular reference to education and training, R & D, technology policy formulation, capital goods, and various other 'North-South' issues. The second part of the chapter focuses on the Commonwealth dimension and recommends new mechanisms for member countries to share their experiences in adjusting to the introduction of new technologies.

II. AREAS FOR INTERNATIONAL COOPERATION

Education and training

3.5 We have already stressed the key role of education and training both in creating an indigenous capacity in relation to new technologies

and in facilitating adjustment. While some developing countries have created a large cadre of scientific and technically skilled manpower themselves—notably India—others need help in training at various levels. All developed countries and most multilateral bodies offer various forms of technical assistance incorporating training, ranging from financial or technical support for the establishment of training institutes, to scholarships for training abroad.[2] In addition there are a number of bilateral commercial initiatives, for example specialised training units set up by foreign firms to develop the skills necessary for their local activities. We consider that much more could be done to strengthen these activities, especially in relation to the 'software' requirements of microelectronics technology, by increasing their funding, particularly for the poorer developing countries where public education is under severe constraints.

3.6 Developing countries' shortages of skilled workers can also be relieved through cooperative efforts, such as the establishment of joint training institutes. As with joint R & D, this will reduce wasteful duplication—for example, in one region of Africa three neighbouring countries, despite having small textile industries, each have their own textile training institutes.

3.7 Skills in and experiences of new technologies can also be acquired by countries exchanging personnel. Such exchanges may take the traditional form of technical assistance—for example skilled workers from the technologically more advanced (developed or developing) countries helping to train workers in less advanced countries—or they may involve workers, managers or policy-makers from the latter gaining technical skills and experience by working in technologically more advanced industries or institutions in the former.[3] Both are desirable but in the second case, measures may be needed to persuade the newly trained personnel to return to their country of origin.

3.8 There is already a large flow of workers between countries. For some developing countries, it involves the migration of skilled workers, in whom they have invested scarce resources in education or training, to other countries with greater economic or professional opportunities. According to UNCTAD the imputed capital value of this 'overflow' or 'brain drain' from developing countries as a whole was roughly equal in value to all bilateral aid during the period analysed.[4] There is also a substantial flow of labour from poor, labour-surplus developing countries to others such as Singapore and countries in the Middle East.

3.9 Offsetting the short-term cost of reduction in the availability of skilled workers (itself partly offset by migrants' remittances of foreign exchange) are the medium-term benefits which are realised when

migrants return home with the experience of working in technologically more advanced industries. For example a large number of entrepreneurs in China (Taiwan), South Korea and the Caribbean have been to the USA, not only for training but also to gain technical and managerial experience and even to set up R & D bases there. It is an example which entrepreneurs in India and elsewhere have begun to follow. Migrants to other developing countries may also acquire new skills. For example, construction workers who go to the Middle East learn how to utilise the heavy equipment in use there.

3.10 But for many countries there is still a problem of skilled nationals being reluctant to return home, because of difficulties in exploiting their technological expertise. In most cases host countries have provided these skilled workers with incentives to stay, in contrast to the treatment of the unskilled. Some form of international labour compensatory facility, as proposed by UNCTAD, may therefore be appropriate. Under it, countries experiencing a large-scale outflow of skilled nationals could be given financial assistance, to be spent on expanding training schemes, foreign fellowships, or equipment to substitute for skilled labour, as relevant.

Joint research and development

3.11 There is growing recognition of the need for collaborative R & D, especially among small states and on matters of importance to developing countries. Among the more significant institutions in this respect is the International Rice Research Institute, which has played a major role in developing new seed varieties. Other institutions have concentrated on high-tech areas; for example, the International Centre for Genetic Engineering and Biotechnology which is being established (at the initiative of UNIDO) with sites in Italy (Trieste) and India (New Delhi). This Centre will concentrate on R & D (including setting up a gene bank) and training in industrial microbiology, agriculture and health, with particular attention to the needs of developing countries.[5]

3.12 While producing valuable research themselves, these international institutions have had difficulty in helping governments to minimise duplication in their national research programmes. A survey by the Asian Institute of Technology in 1983 found that each of 15 alternative energy sources was being studied by at least three of the five ASEAN countries, while six sources were being studied in all five countries. There are several regional centres which could help to coordinate R & D; examples include the Africa Regional Centre for Technology and the ESCAP Regional Centre for Research and Development of Coarse Grains, Pulses, Roots and Tuber Crops in the Humid Tropics of Asia and the Pacific. Given the important role the centres can play, they seem generally to be underfunded.

3.13 Another important area for cooperation is the dissemination of information about R & D. Such information is important for countries to take account of the implications for their own economies of developments elsewhere and to minimise R & D duplication.[6] While there are mechanisms for the results of most aid-funded research in developed countries to be channelled to developing countries, there is little institutional support for the transfer to developing countries of information about other R & D generated in the public sector. UNCTAD has proposed that information about technologies in the public domain (publicly funded R & D and patents which have lapsed) should be made available to developing countries on concessional terms. The information could be included in existing international data-bases, such as the UNIDO Industrial and Technological Information Bank or the WIPO International Patent Documentation Centre, or incorporated in a new data-base, together with information on the results of UN-funded R & D which have not been assembled elsewhere.

3.14 In addition, the UN agencies produce a number of basic bibliographical or reference systems covering R & D projects, technology sources, patent documentation or training and technical assistance programmes.[7] The purpose of the Advanced Technology Alert System (ATAS), launched recently by UNCSTD, is to provide developing countries with information about emerging developments in the frontier areas of science and technology, and the implications for their economies. An international network of specialised research institutions and experts will monitor technological developments and select relevant information for dissemination to developing country planners and scientists via seminars and publications (notably the ATAS *Bulletin*). The information may eventually be made available via a computer network.

3.15 Some form of coordinating or switching mechanism is however needed to channel inquiries about technological developments to the appropriate information system. It is also desirable to link the UN network with some of the commercial data banks, provided their owners allow developing countries to use the information at rates they can afford. International information networks may also help improve contacts between small- or medium-scale industries in developing countries. Some such mechanisms already operate. For example the UNIDO monthly newsletter publishes lists of companies offering (and seeking) various technology packages, and the Centre for Industrial Development, set up under the Lome Convention between the EEC and 66 African, Caribbean and Pacific countries, provides a similar service for member countries. The International Technology for the People Fairs provide an opportunity for developing countries to become acquainted with a wide range of technologies in such basic needs areas

as food production and processing, housing, energy, and health. These initiatives are rather fragmentary and there is a case for better coordination, perhaps even integrating them into a single information network easily accessible to entrepreneurs (and governments) in both developing and developed countries; one possibility might be to use the UNDP Information Referral System as a basis.

3.16 Finally, most developing countries need both financial and technical support to develop their information infrastructure. As well as financial assistance with the hardware, technical assistance could help utilise information sources and improve domestic information collection and processing capacity. A further requirement is a capacity to standardise technology information systems to ensure that the information is more easily shared.

Technology policy formulation

3.17 Nearly all major multilateral agencies have an active interest in the management of technological change, in the case of the UN stimulated by agreement on the Vienna Programme of Action in 1979.[8] The UNCTAD Advisory Service on the Transfer of Technology assists developing countries to formulate technology plans, with special attention to critical sectors such as energy, food processing and capital goods. Other agencies offer advice on policy in their own fields of expertise, for example, UNIDO in industrial technology, and FAO in food technology. As well as the terms of technology transfer, much of the emphasis is on the actual or likely impact of new technologies. For example, ILO is concerned with their implications for employment and working conditions,[9] and UNESCO with those for education. There would appear to be scope for greater coordination of these activities to avoid overlap and to ensure consistent advice. The UN Financing System for Science and Technology for Development, UNIDO, and others have organised international seminars on country experiences in technology policy-making; but much more could be done. What does appear to be lacking, however, is an effective input from international agencies, and especially from the World Bank, into technology policy formulation. This is increasingly important in connection with the growing emphasis on policy conditionality and dialogue at a national and sectoral level in association with structural adjustment lending.

3.18 There are several ways in which developing countries can provide mutual support at the policy level. One is to exchange experiences they have had in negotiating contracts with foreign suppliers of technology or in managing the impact of these technologies. Institutional mechanisms for exchanges of this type have been developed, such as the regional conferences organised by UNESCO for ministers responsible

for the application of science and technology for development; various inter-governmental groups of experts have also been established. Such mechanisms should be assisted by relevant information networks. Examples include the Technology Information Pilot System (TIPS) being developed by UNDP for ten developing countries,[10] covering technology transfer, trade and investment needs, business opportunities, etc., in seven new technologies and a traditional one; and UNIDO's Technology International Exchange System (TIES), which disseminates information on commercial technology contracts.

3.19 In addition developing countries could harmonise their technology practices on a regional basis, if not more widely, if they want to stimulate greater cooperation in trade and investment. In particular, common technical standards would facilitate the compatability of information systems (allowing software and data banks to be shared) and production systems (allowing countries to specialise in producing different products or parts, and thereby realise economies of scale). The experience of the EEC, where failure to adopt common standards has frustrated both R & D and production plans, should be a lesson for developing countries interested in promoting regional development.

Acquiring capital goods

3.20 To the extent that some technology is embodied in hardware, there is an argument for extending cooperation to the acquisition of capital goods. Developed countries have provided developing countries with subsidised export credits and bilateral aid tied to capital purchases. In practice, however, the technology which developing countries are being helped to buy may not be as appropriate as others which are not on 'special offer'. In this case the subsidies may be more effective if they are channelled through multilateral agencies for use in the acquisition of new technologies appropriate to developing countries.

3.21 Cooperation among developing countries has led to a substantial increase in their mutual trade in capital goods.[11] Despite the growth of this trade, the volume might be even larger were it not for various information gaps, financial difficulties and institutional and infrastructural barriers which hinder South-South trade in these and other products.[12] The case for removing these barriers to capital goods trade rests largely on the assumption that goods developed or adapted in one developing country may be more appropriate for another such country than are those imported from developed countries. Certainly, for the least developed, technologically-backward, developing countries, it may be easier to assimilate technologies which have been tried, digested and adapted by other developing countries, than those imported directly from developed countries, with whom there is a large technology gap;

in particular, such technologies should reduce the least developed countries' need for costly trial and error procedures.

3.22 But disadvantages are possible, similar to those arising from buying capital goods from developed countries. For example, the risk of becoming dependent on the technology supplier for spare parts (or even for management of the plant where the technological know-how is not fully transferred); restrictions on the use of equipment for the production of goods for export; or technological obsolescence. It is also likely that technologies imported from other developing countries are even further behind the state of the art (let alone best practices) than those purchased from developed countries. While in some cases this may make them more appropriate, in others it may make them simply less efficient.

Other areas for cooperation

3.23 There are several other issues 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, and the interaction between technological change and international trade. There are also many other areas which have indirect but important implications for technological change, such as the UN Convention on the Law of the Sea or the UNCTAD Common Fund for Commodities. All call for a consensual rather than confrontational approach. Here for illustrative purposes we focus on four issues of direct relevance.

3.24 The first issue concerns *international codes of conduct* for the transfer of technology. Essentially the concern is for a balance to be struck between improving developing countries' access to new technologies on fair terms, and ensuring that foreign companies are not deterred from developing and transferring their technologies, whether under an investment package or through the sale of goods or services. Since the mid-1970s there have been efforts in UNCTAD to draw up a code of conduct on technology transfer similar to that governing restrictive business practices or sought in the UN Commission on Transnational Corporations for the activities of such enterprises. Despite six years of negotiations in UNCTAD, there are still several major areas of difference between the developed and developing country groups. They include such basic issues as whether the laws of the technology supplying or receiving country should govern technology transactions, how disputes would be settled, and how the code should apply to transactions between related parties. Even if agreement is reached on such matters, the code is unlikely to be mandatory.

3.25 Another issue relates to *access to high-technology products.* Fifteen countries (14 members of NATO and Japan) have long operated

a Coordinating Committee (Cocom) to restrict exports of certain high-tech goods, including computers, robots, and sophisticated electronic and telecommunications products, to socialist countries, primarily in Eastern Europe. However, Cocom has recently extended its export controls to 12 developing countries, including Hong Kong, India, Malaysia and Singapore, on the alleged grounds that importers in these countries are 'unreliable', i.e they are suspected of having re-exported Cocom listed products to socialist countries (or of attempting to do so). In some cases this has led to lengthy delays before technology export licences to these countries have been granted, and sometimes they have been refused.[13] Moreover, although the initial rationale for the Cocom system was one of security, it has become increasingly difficult to distinguish between products of civil and of military application (many are in fact 'dual use'), with the result that controls have begun to affect imports by developing countries of high-tech products which have important industrial uses. Controlled products include electronics and semiconductor manufacturing equipment; measuring and calibration equipment; microcircuits and integrated circuits; computers; silicon chips and other components; sapphire substrates; and carbon technology. It is not clear whether there are also non-security motives (for example a desire to restrict industrial competition), but the volumes of trade involved may be considerable, while the upgrading of manufacturing capacity will also be affected indirectly.[14] This development illustrates some of the problems involved with dependence on a few, quasi-cartelised, companies for high-technology imports.

3.26 A third area of concern relates to *copyrights and counterfeiting*. According to EEC estimates as much as 2 per cent of international trade is now in counterfeit goods, i.e. those which are produced in contravention of copyright law, including illicit copies or goods using trademarks falsely. This trade occurs in both developed and developing countries. In many cases the issue is not one of techology, *per se,* but how to protect consumers from copies which are often inferior if not totally unreliable. For example, counterfeit antibiotics, birth control pills, and fungicides have caused widespread damage. The use of the latter by West African cocoa farmers and East African coffee farmers allegedly contributed to harvest losses of some $20 million in each case. Developed countries are concerned by the implications not only for their consumers, but also for their producers—manufacturers of car parts in Europe claim to have lost 6,000 jobs (a year) as a result of counterfeit parts imported from three developing countries alone, while in the USA some 14,000 jobs are said to have been lost through this means. Counterfeiting has also spread to high-tech products such as computers and related software; here the problem consists both of copying firms being able to produce goods of similar quality but at lower prices (as they have no R & D costs to defray) and of poor

quality goods falsely marked with trademarks associated with high quality products. Developed country producers and governments have attempted to resolve the matter under the Paris Convention on Industrial Property Rights[15] by seeking to strengthen patent protection in developing countries. They argue that unless developed country firms have some means of recouping their R & D costs, these firms will be reluctant to reveal details of their new products, whether through patents or other means, while their willingness to invest in R & D could also be dampened. But developing countries have different, and to some extent opposing, interests—seeking greater and concessional access to patent information, such as the ability to suspend patents if licences are not fully used, and shorter periods for which licences are valid. They also fear that to enforce restrictions on the use of intellectual property rights would be to keep developing countries technologically backward.

3.27 The fourth area to which we wish to refer is that of *transborder data flows*. Here, developing countries are concerned not only with access to such data but with implications which it has for their sovereignty. While transborder data flows can bring enormous potential benefits (for example providing developing countries with information on the international commodity and technology markets), they also raise a number of problems. One is the likelihood of increasing external dependence for data processing. Another is control over data use—which may be sensitive if strategic sectors are involved. A third is the greater centralisation of decision-making, especially by transnational corporations. Some developed countries share these concerns and there have been a number of efforts to draw up international guidelines for transborder data flows, in the Intergovernmental Bureau for Informatics, the OECD and elsewhere. However before there can be much progress, more in-depth evaluation of the impact on individual countries is needed.

III. AREAS FOR COMMONWEALTH COOPERATION

3.28 After broadly analysing the impact of new technologies (Chapter 1), setting out some of the principles and experiences of policy to 'manage' technology (Chapter 2) and recommending ways in which the international community can help developing countries to maximise their benefits from new technologies, we addressed the question of how the Commonwealth could assist. We paid particular attention to the role that could be played by the Commonwealth Secretariat and, where appropriate, the Commonwealth Science Council (CSC). In doing so we were aware of the funding contraints involved in suggesting 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.

3.29 By the end of our deliberations we concluded that there is an important role for the Commonwealth Secretariat in encouraging or carrying out certain information and promotion activities and advisory services, as well as in organising training courses and seminars on the management of technological change. We decided to make recommendations on each of these, though it should be understood that these are merely of an indicative nature and are for purposes of illustration. More detailed assessment, including costing, would need to be undertaken on their implications before a properly informed decision could be made, though in our view this would not preclude governments from making a commitment in principle.

Information and promotion activities

3.30 As we have shown in earlier parts of our Report, a large number of developments are occurring in the technological field, particularly in the emerging technologies, with important implications for economic and social activity worldwide. For most Commonwealth developing countries it is very difficult, if not impossible, to keep abreast of these changes, let alone to be in a position to evaluate the likely impact on their economies. Although a great deal of work on many facets of technological change is being undertaken in several United Nations' organs, notably UNCSTD, UNIDO and ILO, which is of considerable interest to developing countries, many also lack the capacity to keep up with this work. We therefore examined whether the Commonwealth Secretariat might itself perform a useful function by monitoring developments and disseminating information in an easily accessible and digestible form to decision-makers in Commonwealth governments and also to non-governmental organisations (NGOs). In this context it could draw on its network of contacts and its experience of supporting the work of decision-makers, especially in small states.

3.31 It also became clear, in the course of our work, that there is little readily available data on the economic and social impact (particularly on employment) of new technologies in most Commonwealth countries. Such information is crucial for technology assessment in the countries to which it refers, while it can provide important lessons for others. Although the ILO, in particular the newly-established ILO Advisory Committee on Technology, is doing some work in this area, we feel that the Commonwealth Secretariat can usefully encourage Commonwealth countries to collect such information and help in its dissemination. We

have therefore given careful thought to the nature of the Secretariat's possible involvement in this area. One possibility would be for it to carry out or commission studies to widen understanding. For example, it would be useful if the Secretariat initiated comparative studies of the impact in different environments of the same technologies.

3.32 Another approach would be to concentrate on the dissemination of information already available, using expertise in the Secretariat, particularly in the Commonwealth Science Adviser's Office, the Industrial Development Unit (IDU) and the Economic Affairs Division. For example, the CSC's Earth Sciences Newsletter and other publications already document certain changes relevant to new technologies. The IDU is currently designing data bases on industrial technologies and processes required by some member countries and Commonwealth regional organisations, as part of its ongoing project work for the implementation of subcontracting exchanges and information centres.

3.33 We feel that in addition it would be desirable and feasible to compile, and distribute to member governments, a quarterly newsletter aimed at policy- and decision-makers and covering, together or separately, technical and socio-economic aspects of developments concerning new technologies. The information would be in a summary form with references to sources for those interested in obtaining further details. The groups of new technologies and sectors of application to be covered would depend partly on the resources available and partly on countries' requests. There are other modes of transmitting such information—for example via micro-computers linked to a data bank, by 'talking' word-processors, facsimile machines, or even satellites—and consideration could be given to incorporating some of these once the simpler means of communication had been established and proved to meet a need.

3.34 At the same time, action should be taken to raise member states' knowledge of the existing technology-related activities being undertaken by the Commonwealth Secretariat. Equally, the technology-related work of the CSC and Commonwealth NGOs should be more widely recognised and, in so far as practical, coordinated with that of the Secretariat.

3.35 At the very least, a concerted effort is required to ensure that the importance of technology policy and the need to formulate quick responses to accomodate major new technologies are kept to the forefront of future meetings of Commonwealth Employment/Labour Ministers and of other Ministers, including Ministers of Planning, Education, Industry, Agriculture, Finance and Trade.

Advisory services

3.36 The Commonwealth Secretariat as well as several Commonwealth NGOs already provide their respective constituents with a range of advisory services relating to the assessment and use of technology. To date, however, there has been little focus on the actual or potential use of 'new', as opposed to 'traditional', technologies, or on the possibilities of 'blending' the two, especially in developing countries. The material submitted to us has shown that the technology requirements of Commonwealth countries differ very considerably, according to a whole range of considerations. Nevertheless, all countries need to optimise their use of technology, in the choice of which they should take account of all its economic and social effects, not least on employment. In addition they must be prepared for future technological changes.

3.37 The speed of technological change and plethora of new technologies available mean that many governments, particularly of developing countries, will need to seek external advice on technology identification, assessment, application and forecasting. For this reason they are turning progressively towards international institutions for impartial guidance. The Commonwealth Secretariat should expect to receive an increasing number of detailed requests for such advice. If it is to respond to them, it will have to strengthen its capacity. This will need additional resources. We are especially aware of the gravity of the present situation in Africa and believe that a strong case can be made for a special effort to increase advisory services to African member countries on how new technology (for example biotechnology) might be used to meet their urgent needs, particularly in relation to food supply.

3.38 There is also merit in an advisory panel of experts who could be drawn upon as the need arose. As well as being available to provide advice on technology forecasting or assessment, the panel would be able to help Commonwealth developing countries to develop technology institutions and improve contacts between them.

Training and exchange programmes and education

3.39 The choice of the most appropriate new technology and its effective deployment is dependent on a greater understanding by decision-makers of the technological options available. The Commonwealth can play an important role in this respect by organising training or exchange programmes for key personnel, with the aim of creating a better awareness of new technologies and their impact. In the first instance such initiatives should be directed at those who decide on the use of new technologies rather than at the operators of those technologies.

3.40 Government officials, scientific advisers, managers and trade unionists are all directly concerned with the choice of new technologies. In many cases they need greater knowledge of the systems available, in order to negotiate effectively on the acquisition of new technology or its use at the workplace. One way of enabling decision-makers to acquaint themselves with the uses and implications of new technologies, and how they are best managed, would be through contacts with others in Commonwealth countries who have had comparable experiences and problems. This could be done through instituting exchange schemes in a manner somewhat analogous to those which already exist in other spheres, for example among senior officials for regional integration secretariats. Further, seminars for representatives of both the public and private sectors could be organised on a regional or wider basis specifically to learn from experiences in the use of new technologies.

3.41 The Commonwealth Industrial Training and Experience Programme (CITEP), which would give trainees up to six months' industrial training or experience in other Commonwealth countries, would have a significant role to play. It would provide training opportunities, not only for technology decision-makers but also for operators of new technology, especially in the less developed small island states and those in special need in sub-Saharan Africa, where such opportunities are limited. We were pleased to hear that at the June 1985 meeting of Commonwealth Employment/Labour Ministers, several Ministers spoke in favour of CITEP giving priority to the training of key personnel in the use of new technologies. In that connection we suggest that the possibility is investigated of co-financing from a variety of sources, including manufacturing companies, which have an interest in promoting technological diffusion, and other international bodies working in this field. Meetings of Commonwealth Employment/Labour Ministers' should serve as a focal point for reviewing and stimulating future exchange and training arrangements.

3.42 Finally we have been most impressed with the possibilities of making greater use of new technologies to facilitate and promote education. Satellite communication has already been used to bring education to the rural areas of India, where it has been particularly useful in disseminating knowledge on agricultural technologies. We see much wider scope for this means of communication. The combination of satellite technology and English as the common language not only of international communication but also of the Commonwealth, could be used to achieve more cost-efficient education systems, especially in higher and specialist education, throughout the Commonwealth or in particular regions of it. Economies of scale would make such a medium especially suitable for assisting the learning process in small states and the poorer countries which are unable to receive specialist education

through conventional means. We suggest thought should be given to the financial and technical implications of such an idea.

NOTES

1. The EURONET-DIANE network, which was inaugurated at the end of 1984, shows what cooperation can achieve (albeit at considerable cost—$33 million, excluding the cost of the data-bases themselves). It provides access to more than 60 million pieces of scientific, technical, economic and social information, stored in nearly 500 data banks in the public and private sectors, via a data transmission service operated by national post and telecommunications offices. Besides the ten EEC members, Switzerland, Sweden and Finland have joined the network, while Austria and Portugal are likely to do so shortly.
2. Among multilateral bodies the ILO, with its International Centre for Advanced Technical and Vocational Training, is perhaps foremost, but training is also provided by other parts of the UN system, such as UNIDO, and elsewhere including the Commonwealth Fund for Technical Cooperation.
3. This is one type of exchange envisaged under the Commonwealth Industrial Training and Experience Programme (see para 3.41, below).
4. UNDP, *TCDC News*, No. 2, 1983, p. 8.
5. Its resources are however modest. Its budget for the first five years has been set initially at $41 million—barely as much as Japanese public spending on this area in one year. (*New Scientist,* 9 February 1984.)
6. For example, the Socially Appropriate Technology Information Service, based in Senegal, promotes exchanges of information on R & D programmes.
7. See Volume II, Appendix 9 for details.
8. UN activities in science and technology under the Vienna Programme of Action are discussed in more detail in Volume II, Appendix 9.
9. It has recently set up a tripartite Advisory Committee on Technology, representing workers, employers and policy-makers to consider these issues.
10. Brazil, Egypt, India, Indonesia, Kenya, Mexico, Nigeria, Pakistan, Peru, Philippines. The list may later be extended.
11. Comprehensive up-to-date figures are not available, but even by 1980 the share of capital goods in the rapidly-growing total of intra-developing country trade had reached 20 per cent, compared with 4 per cent in 1960. The bulk originates in a few developing countries, notably South Korea, Brazil, India, Argentina and Mexico.

12. See for example, UNCTAD, *Trade and Development Report* 1983, Part II, Economic Cooperation Among Developing Countries.
13. Such problems led to Singapore agreeing in April 1985 to cooperate with Cocom, the first country outside NATO and Japan to do so.
14. For example, in Spain, plans by AT & T to set up microchip production and by Corning Glass to construct a fibre-optics plant have been under threat, putting pressure on the Spanish Government to reconsider its commercial ties with Cuba.
15. The basic legal instrument governing the international use of patents, trademarks, designs, etc, to which almost all developed market economy countries and more than 50 developing countries belong.

Appendix 1

Abbreviations and Glossary

I. ABBREVIATIONS

ASEAN	Association of South-East Asian Nations
ATM	Automated teller machine
ATAS	Advance Technology Alert System
CAD	Computer-aided design
CAM	Computer-aided manufacture
CITEP	Commonwealth Industrial Training and Experience Programme
CNC	Computer-numerically-controlled
CPU	Central processing unit
CSC	Commonwealth Science Council
DNA	Deoxyribonucleic acid
EEC	European Economic Community
ESCAP	Economic and Social Commission for Asia and the Pacific
FMS	Flexible manufacturing system
GDP	Gross domestic product
GNP	Gross national product
HSLA	High-strength low-alloy
HYV	High yielding variety
IC	Integrated circuit
ILO	International Labour Office
kW	Kilowatt
MCA	Monoclonal antibody
MFA	Multifibre Arrangement
MW	Megawatt
NCMT	Numerically-controlled machine tool
NGO	Non-governmental organisation
NIC	Newly industrialising country

OECD	Organization for Economic Cooperation and Development
PV	Photovoltaic
RAM	Random access memory
R & D	Research and development
rDNA	Recombinant deoxyribonucleic acid
S & T	Science and technology
TNC	Transnational corporation
UN	United Nations
UNCSTD	UN Centre for Science and Technology for Development
UNCTAD	UN Conference on Trade and Development
UNDP	UN Development Programme
UNESCO	UN Educational, Scientific and Cultural Organization
UNIDO	UN Industrial Development Organization
VCR	Video cassette recorder
VDU	Visual display unit
VLSI	Very large scale integration
WIPO	World Intellectual Property Organization

II. GLOSSARY

Appropriate technology. This may be defined as the set of techniques which make optimum use of available resources in a given environment. For each process or project, it is the technology that maximises social welfare if factor prices are shadow-priced.

Basic needs. This term includes several elements: first, certain minimum requirements of a family for private consumption—adequate food, shelter and clothing, as well as certain items of household equipment and furniture; second, essential services provided by and for the community at large, such as safe drinking water, sanitation, public transport, and health, educational and cultural facilities; and third, freely chosen employment to provide income and self-respect. The concept is a country-specific and dynamic one, which should be seen within the context of a nation's overall economic and social development.

Biotechnology. The application of scientific and engineering principles (particularly those employed in microbiology, biochemistry, genetics, biochemical and chemical engineering) in the processing of materials

by biological agents (such as micro-organisms, enzymes, and animal and plant cells) to produce goods and services.

Central processing unit. The main processing area of a computer which carries out arithmetic, logic and control functions.

Computer. A general term used to describe any machine which processes data according to defined instructions and which is programmable.

Computer-aided design. The use of a computer system to assist in translating a concept into an engineering, construction, or other working design using a data bank of design principles and other information, together with the production of information, including drawings, for the use in manufacturing processes and other productive activities.

Computer-aided manufacture. The use of computer(s), including CAD, as a direct input to control manufacturing equipment (for example, computer-numerically-controlled machine tools, inspection and test equipment, industrial robots, etc.).

Computer-numerically-controlled. Usually refers to machine tools which are numerically controlled by microprocessors to carry out programmable functions.

Deoxyribonucleic acid (DNA). A large, complex organic molecule which carries, coded within its chemical structure, the information for controlling protein synthesis in all living organisms. Hence it controls their physical structure, growth, reproduction and functioning.

Flexible manufacturing systems. The linking of automated manufacturing cells (usually CNC tools and other automated equipment) to an automated transfer line controlled by a computer hierarchy.

Hardware. The physical equipment and components required to build a productive system.

Information technology. The range of telecommunications, telematics and information technologies, centred around microelectronic devices which permit the storage, transmission and manipulation of data in digital form, at low cost and great speed. The term *informatics* is sometimes used to describe this technology.

Invention. An idea or prototype of a new product or process. It does not become an innovation until it reaches the market.

Innovation. An entirely new or technically substantively different product or process which is offered for sale to potential users.

Integrated circuit ('Chip'). A set of electronic components and their interconnections, fulfilling one or more functions and imprinted on a single chip of semiconductor material, generally silicon.

Micro-computer. A small computer using a microprocessor as its central processing unit and with a small number of associated chips.

Microelectronics. A general term to describe the technology associated with large- and very large-scale integrated circuits, particularly microprocessors and memory chips. Frequently used interchangeably with such terms as microtechnology, informatics, etc.

Microprocessor. A central processing unit contained on a single chip. The basis for micro-computers, mini-computers and many other microelectronics products.

Mini-computer. A medium-sized computer with considerable storage and processing power, normally using hard disks as external storage. At the bottom end of the range there is a blurring of distinction with micro-computers; at the top, a similar blurring with mainframe computers.

Monoclonal antibody. An antibody (protein component of the immune system found in mammals' blood) which is derived from a single source clone of cells and which recognises only one kind of antigen.

Newly industrialising countries. Certain developing countries which have built up a substantial (mainly export-oriented) industrial sector, based initially on relatively low labour costs; examples include Argentina, Brazil, Hong Kong, Mexico, Singapore, South Korea and China (Taiwan).

Robot. A reprogrammable, multifunctional mechanical manipulator designed to perform a variety of tasks through variable programmed motions.

Semiconductors. Electronic components made from materials such as silicon or germanium which amplify, switch or rectify electric currents. They include discrete functional devices such as transistors and integrated circuits.

Software. Intellectual creation comprising the programmes, procedures, rules and any associated documentation pertaining to the operation

of a data processing system. Software is independent of the carrier medium.

System. An organised grouping of people, methods, machines, and materials collected together to accomplish a specific task.

Systems analysis. Analysis needed to design a system to meet the defined needs of an organisation for the optimal means of producing goods and services.

Technology assessment. Process for the systematic analysis, forecasting and evaluation of a broad range of impacts on society pertaining to technological change and choice, in order to identify public policies and options. It helps to match technological developments to national goals.

*Technology blending.*The integration of emerging technologies with traditional modes of undertaking production and other activities to ensure higher productivity while retaining some of the traditional characteristics of conventional techniques.

Technology forecasting. Attempts to predict future developments in technology, and future effects of a specific technological development on an economy, society and environment.

Telematics. The fusion of telecommunications and computer technologies made possible by digital electronics. Data in digital form are stored, manipulated and transmitted between computers using public telecommunication transmission networks. A term sometimes used interchangeably with *informatics.*

Videotext/viewdata. Computer/TV/telephone-based information system which gives the subscriber access to textual information on a wide range of subjects via the telephone line.

Visual display unit. A terminal comprising a keyboard for data input and a display screen to monitor the input.

Appendix 2

Terms of reference for working group on the management of technological change

The Working Group is requested to:

(i) examine the existing and potential impact of the adoption of new technologies, particularly microelectronics, on the economies of Commonwealth countries, paying special attention to employment, productivity changes, industrialisation in developing countries, trade between developed and developing countries, and social impact;

(ii) identify appropriate policy measures to facilitate the process of adjustment to these technologies, including training and retraining arrangements, taking into account possible disruptive effects on employment and existing industries; and

(iii) suggest arrangements for the sharing of Commonwealth experience in this field in order to enable Commonwealth countries to derive maximum benefits from new technologies.

Appendix 3

Members of the commonwealth working group on the management of technological change

Professor M. G. K. Menon (Chairman)	Member, Indian Planning Commission and Chairman, Science Advisory Committee to the Cabinet, Government of India. Formerly Secretary, Department of Science and Technology (1978–1982); Director-General, Council of Scientific and Industrial Research (1978–81); Chairman, Electronics Commission and Secretary, Department of Electronics (1971–78).
Dr. Desmond Ali	Deputy-Director, Caribbean Industrial Research Institute, Trinidad & Tobago; formerly Deputy-Secretary, Commonwealth Science Council (1980–83).
Dr. M. N. B. Ayiku	Coordinator, Technology Transfer Centre, Council for Scientific and Industrial Research, Ghana; Chairman, meeting on intra-ACP cooperation in transfer of technology, Brussels, November 1983.
Mr. Iann Barron	Managing Director, Inmos Limited; member of Alvey Committee on a Programme for Advanced Information Technology (United Kingdom), 1982; founder-member, Computer Technology Limited.
Mrs. Shirley Carr	Secretary-Treasurer, Canadian Labour Congress; member of Governing Body, ILO; co-chairperson, Labour Market and Productivity Centre, Canada.

Dr. David Gachuki	Faculty of Law, University of Nairobi; consultant, East Africa Technology Policy Study, International Development and Research Centre of Canada, Regional Office, Nairobi, Kenya.
Dr. Linda Lim	Centre for South and Southeast Asian Studies, University of Michigan, USA; consultant to United Nations (including ILO, ESCAP, UNCTC and UNIDO).
Sir Bruce Williams	Director, Technical Change Centre, London; formerly Vice-Chancellor and Principal, University of Sydney (1967–81).
Mr. Carl Wright	Director, Commonwealth Trade Union Council; formerly Labour Adviser, UN Centre on Transnational Corporations (1978–80) and Secretary, Economic and Social Committee, International Confederation of Free Trade Unions, Brussels (1974–80).

Commonwealth Secretariat

Sir Peter Marshall	Deputy Secretary-General (Economic)

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Ms. A. M. Weston	Senior Economics Officer

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TECHNOLOGICAL CHANGE
Enhancing the Benefits
VOLUME I

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. . . . Different societies will vary enormously in the technological capacity they can realise because of differences of size, income levels and stage of development; but even the smallest and poorest countries need some capacity to make choices and to adapt technology to local conditions.

From the Report

Among policy makers in developing countries, emerging technologies are often regarded with apprehension. This is induced by a sense of impotence; also by a feeling that what is appropriate in richer countries may not be so in poor ones. These fears are understandable. But the Group's Report gives abundant evidence that where technology is directed, and adapted, to meet the needs of low-income groups, it can be a powerful force for good, especially in agriculture and rural development, where in many forms it could be even directly employment-generating. . . . Because of technology, human societies have it in their power to raise living standards worldwide and thus eradicate mass poverty and hunger.

From the Foreword by the Commonwealth Secretary-General

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VOLUME II

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Technological Change Enhancing the Benefits

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Contents

VOLUME II

		Page
APPENDIX 1	MICROELECTRONICS TECHNOLOGY AND THE ELECTRONICS SECTOR	1
	Introduction	1
	Impacts of new technologies on the electronics sector	4
	Conclusion	16
2	INDUSTRIAL APPLICATIONS OF MICROELECTRONICS: THE TEXTILES, CLOTHING AND ENGINEERING INDUSTRIES	18
	Introduction	18
	Textiles and clothing	19
	Engineering	26
3	INFORMATION TECHNOLOGY AND THE SERVICE SECTOR	37
	Overview	37
	Major service industries	40
4	BIOTECHNOLOGY	49
	Development of traditional and new biotechnology	49
	Biotechnology applications	51
	Biotechnology research and development	59

		Page
	Biotechnology and developing countries: impacts and issues	61
	Conclusion	64
5	NEW MATERIALS TECHNOLOGIES	67
	General trends	67
	Selected developments	68
	Government support	71
	Implications for developing countries	72
6	RENEWABLE ENERGY TECHNOLOGIES	73
	The setting	73
	Development and applications	75
	Economic and social impact	83
	Problems and potentials for developing countries	85
7	ILO RECOMMENDATION ON EMPLOYMENT POLICY: TECHNOLOGY POLICIES	89
8	A CONSULTANT'S NOTE ON NEW TECHNOLOGY AGREEMENTS	92
9	UN ACTIVITIES IN SCIENCE AND TECHNOLOGY UNDER THE VIENNA PROGRAMME OF ACTION	97
10	SELECTED BIBLIOGRAPHY	107

TABLE 1.1	Consumption of electronics equipment by major industrial countries, 1984	2
1.2	End-use distribution of integrated circuits, 1982	3
1.3	Estimated minimum investment for semiconductor production	7
1.4	Effect of changes in technology on the composition of the labour force	8
1.5	Manufacturing cost per electronic device	12

		Page
2.1	Applications of information technology in engineering processes	27
2.2	Recent technological changes in the Japanese automobile industry	28
2.3	Production of and demand for CNC lathes in selected countries	30
2.4	Population of robots	32
2.5	Final products incorporating parts manufactured by FMS in OECD countries	33
4.1	Major recent events in the commercialisation of biotechnology	52
4.2	Implementation of genetic engineering procedures: some market predictions	53
4.3	Biotechnology uses and products and some market forecasts	54
4.4	Value of applied genetics and new biotechnologies in various market segments in the United States	56
4.5	Public funds for biotechnology R & D, 1982	59
4.6	Biotechnology organisations in healthcare	60
8.1	Summary of procedures of joint regulation of technological change in selected countries	94

Appendix 1

Microelectronics Technology and the Electronics Sector

I. INTRODUCTION

1.1 The application of microelectronics and information technologies is well advanced, and industries incorporating these technologies are expected to become the world's largest and most rapidly expanding economic sector during the second half of the 1980s.

1.2 The world electronics equipment market has expanded dramatically over the past fifteen years, from sales of some $50 billion in 1970 to an estimated $380 billion in 1985 (current values in each case). Although semiconductors are critical components, they usually constitute only a small fraction of total electronics equipment systems and costs. The demand for semiconductors has been expanding more rapidly, though at a lower level, than that for electronics equipment, rising in current values from $2.2 billion to approximately $35 billion over the same period; this trend is expected to continue in the long run, despite some cyclical fluctuations as, for instance, the one being experienced in 1985.

1.3 The use of semiconductors in the developing countries is very limited, and that in the centrally-planned economies is not very marked. Together their consumption was less than 10 per cent of the world total in 1983, while they produced only 2 per cent of the world supply. The most important developing country producers of semiconductors are the Asian newly industrialising countries (NICs). For example, of the $4 billion of semiconductors imported by the United States in 1982, $3 billion came from US offshore facilities in four Asian countries: Malaysia, Philippines, Singapore and South Korea.

1.4 The United States and Japan are net exporters of semiconductors: the United States produces nearly two-thirds and consumes about one-half of world production; and Japan produces more than one-quarter and consumes rather less. Western Europe, on the other hand, is a net importer, consuming about one-fifth of world production of semiconductors and producing less than half that proportion.

1.5 Consumption of different types of electronics equipment in the major industrial countries in 1984, given in Table 1.1 below, shows the dominance of data processing and office equipment and of the importance of the industrial and military sector usage in the United States. Similar information is not available for developing countries, but the approximate order of importance is likely to be industrial and military applications, data processing (computers), and consumer products.

Table 1.1

Consumption of Electronics Equipment by Major Industrial Countries, 1984

(US$ billion)

	USA		*Western Europe*	*Japan*
Data processing and office equipment	79.0	Data processing and office equipment	60.5	41.8
Software	15.0			
Consumer products	21.3	Consumer products	15.8	11.2
Communications	11.5	Communications	12.8	3.0
Industrial and military	57.1	Industrial and others	15.8	21.6
Total	184.0	Total	104.9	77.6

Source: Lalor (1984) p. 9.

1.6 Statistics on the product and sector use of microelectronics are also available only for industrial countries, and in any case are not always internationally comparable. However, Table 1.2, which indicates orders of magnitude, shows that whereas computers were the dominant end-user of integrated circuits (ICs) in the United States, consumer products were pre-eminent in Japan. In Western Europe, computers, consumer products, communications and other industrial uses were all of approximately equal importance.

Table 1.2

End-use Distribution of Integrated Circuits, 1982
(Percentages of sales)

	USA	*Japan*	*Western Europe*
Industrial	**72**	**49**	**70**
Computer	40	13	25
Communications	21	10	20
Office automation equipment	5	19	25
Other industrial	6	7	
Consumer	**11**	**51**	**25**
TV/VCR		22	
Audio		14	
Other consumer		15	
Government/Military	**17**	**0**	**5**
Total	100	100	100
($ million)	(7,269)	(2,580)	(1,988)

Source: OECD (1985) p. 20.

1.7 Data on trends in microelectronics technology applications in developing countries are scarce, usually imprecise and often inconsistent. An examination of the major categories of computers (including software), industrial applications, and telecommunications shows that their diffusion is very limited. Developing countries therefore consume only a very small fraction of the world's semiconductors, perhaps only one per cent of ICs and two per cent of microprocessors.[1]

1.8 On the other hand, computer imports into the more industrially advanced developing countries have been quite dynamic in recent years, registering annual growth of between 30 and 40 per cent in some cases. The main importers (Asian and Latin American NICs) tend to demand the same kind of highly complex devices and electronic capital goods as the developed countries. Aggregate data are not available on the sectoral use of computers in developing countries but the most rapid growth has probably been in the public sector, followed by services and then industry. Typically the first computers used in developing countries were mainframes, often imported by subsidiaries of foreign companies for routine clerical work. Government purchases soon followed and the public sector remains the dominant user of mainframes. With the emergence of mini- and then micro-computers the situation

changed significantly, and the use of mini-computers increased markedly during the 1970s. Data on micro-computers are more difficult to obtain but it seems that their use is increasing even in the poorer countries (in Bangladesh, for instance, only six micros were known to be in use in 1980 but by 1984 there were more than 150).

1.9 With the proliferation and declining cost of computing systems, demand for computer services[2] has grown exceedingly fast—much quicker than for most categories of computers. Although global estimates vary, the OECD Secretariat has assessed computer service revenues at $30.5 billion in the United States in 1982, $3.5 billion in Japan in the same year, and $16.2 billion in Western Europe in 1985. Figures for software production and use in developing countries are virtually non-existent. However, it is relevant to note that since the early 1970s, the value of software imports has exceeded that of hardware, and with the increasing, albeit still low, levels of computerisation in the developing countries, this generally constitutes an area of growing technological dependence. The only exceptions are those countries, such as South Korea, Singapore, India and Argentina, which are building up their own computer capabilities.

II. IMPACTS OF NEW TECHNOLOGIES ON THE ELECTRONICS SECTOR

Overview

1.10 The electronics sector encompasses a range of related industries. These can be categorised in various ways but here we divide the sector into: electronic components; consumer electronics; telecommunications;[3] computers; and software peripherals. These groups can of course be further subdivided; for example, within the components industry the main focus has been on semiconductor products.[4]

1.11 The variety of products emanating from the electronics sector, and their increasing application to the processes and products of other sectors, has caused microelectronics to be considered an essential element in the economic development of the modern state. The emergence of what has been called a 'new technological paradigm based on semiconductor developments'[5] has been at the heart of the microelectronics revolution which is currently affecting all industry groups within the electronics sector as well as a whole range of other economic sectors.

Electronic components

1.12 While it may be difficult to separate out the wide variety of what might be classified as electronic components, there is no doubt that the

impact of semiconductor technology is at the core of the microelectronics revolution. It is on semiconductors that this section therefore focuses. The products of the semiconductor industry can be classified in a number of ways—in terms of their function (discrete devices/integrated circuits/special purpose devices); by the technology involved in their fabrication (bipolar or metal oxide); or by their scale of integration on a chip (from small-scale integration (SSI), with 30–80 transistors, to very large-scale integration (VLSI), with about one million transistors). The main and fastest growing product of the industry is the integrated circuit, and this is the area in which there is the greatest R & D effort, the greatest product innovation and the most significant impact on end-users.

1.13 The evolution of the semiconductor industry reflects a process of continuous technological change. This has increased the degree of product integration, improved product performance and reliability, enlarged the number of products, and caused a massive reduction in costs per device and per unit (bit) of processed information.

1.14 The semiconductor industry also possesses a number of features which distinguish it from other electronic sub-sectors. These include the high levels of capital intensity; high dependence on sophisticated and specialised scientific and engineering skills; high degrees of interrelationship between the industry, its suppliers and end-users; and the dominance of US know-how and markets. Perhaps the most important of these characteristics is the pervasiveness of its technologies in end-user sectors: the impact of techological change in the semiconductor industry cannot be dissociated from that in end-user industries such as computers, industrial applications, military equipment. This has led both to closer linkages between semiconductor producers and end-users, and to backward linkages by end-users into semiconductor design and production. Another aspect of the interdependence of the semiconductor industry is its reliance on a range of specialist suppliers, with the high rate of product innovation requiring greater than usual dialogue between suppliers (whether of materials or knowledge inputs) and producers.

1.15 The results of the increased application of, and demand for, semiconductors are reflected in the increase in production, from a world-wide value of $400 million in 1959, to $1.7 billion in 1969, $15.4 billion in 1979, and an estimated $35 billion in 1985. Given that the reductions in unit cost have significantly exceeded the rise in values caused by inflation, these figures obviously underestimate the volume of growth in semiconductor production. But the increase has not been a steady one, and despite the close relationship of semiconductor suppliers and end-users, there have been marked swings in demand. For example, there was recession during 1974–75 and a slump in 1983;

though there was some recovery in 1984, demand in 1985 has been disappointingly sluggish and considerable excess capacity has reappeared in the industry.

1.16 The geographical concentration of the industry is such that in 1983 the United States, Japan and Western Europe together accounted for 98 per cent of world production of semiconductors and a slightly higher share of that of ICs. The United States alone accounted for 73 per cent of IC production in 1980 but, like that of Europe, its proportion has since decreased, whereas that of Japan has increased.

1.17 This expansion in world production has been accompanied by considerable changes in the nature of the semiconductor industry. Until the 1960s it had been characterised by low barriers to entry and expansion. Many of the small firms that entered at that time (particularly in the United States) grew substantially both in size and in market share. But even by the mid-1960s, firms in Western Europe and Japan began to face considerably greater difficulties in entry, because of the increasing complexity of semiconductor products, the technological lead of earlier entrants and the higher R & D costs necessary to be competitive. Despite this 'classical maturation' process, the continuing product and process innovation in the semiconductor industry emphasised its increasing capital intensity and reliance on a high degree of specialisation by skilled workers. The requirement for higher capital expenditures reflects the increased complexity of the products, with consequently more sophisticated production processes and a need for more sophisticated quality control. One estimate[6] of the minimum investment for semiconductor production suggests an increase from $100,000 in 1954 to $60 million in 1982 (see Table 1.3 on facing page).

1.18 These increases in capital costs have been paralleled by increases in R & D costs. The industry is characterised by high technical and commercial risks, which are magnified by its rapid product innovation and obsolescence. In order to maintain a competitive position, firms must devote considerable resources to R & D, especially since the increased competition caused by the rise of production in Japan. But though R & D expenditures have risen markedly, their size as a proportion of sales has tended to remain fairly steady, ranging from around 8–10 per cent in the United States to 13–15 per cent in Japan.

1.19 The complexity and dynamism of semiconductor technologies have also had impacts on the pricing policies of major companies. Learning-curve economies, together with economies of scale and predatory pricing to establish market shares, have reduced the ability of new producers to enter the market and favoured larger companies over smaller ones.

Table 1.3

Estimated Minimum Investment for Semiconductor Production

Year	*$ Required*
1954	100,000
1958	300,000
1967	500,000 (a)
1972	2,000,000 (a)
1976	5,000,000 (a)
1978	10,000,000 (a)
1982	60,000,000 (b)

(a) Wafer fabrication only.
(b) Total wafer-assembly cost.
Source: Truel (1980).

1.20 All these elements have combined to alter the minimum efficient scale of semiconductor production. Larger companies are in a much better position than smaller ones in terms of their ability to obtain capital and skilled labour, and thus in their capacity to undertake R & D and maximise scale economies in production, and hence to follow aggressive pricing policies. While there are differences within the industry (for example in degrees of integration, or production of standardised compared with customised products), there is no doubt that size has become a very important barrier to entry into the semiconductor industry. Its effectiveness is evident from the recent intensification of efforts at national or supra-national cooperation, particularly in R & D, as in the case of the EEC Esprit programme. The quest to achieve larger scale has also contributed to the increasing trend for large companies (including transnational corporations (TNCs) and national or international consortia) to acquire smaller companies. There are two inter-related issues. First, many large companies are seeking rapid access to 'frontier' technologies which may sometimes be developed in smaller firms. Secondly, smaller companies are recognising a growing need for collaboration if they are to increase their access to the capital necessary to produce effectively in an increasingly competitive international market.

1.21 The impact of new technologies in the semiconductor industry has also been significant in terms of changing skill requirements. Evidence shows a continuing decrease in production workers as a proportion of the industry's labour force. Skilled workers (such as technologists, engineers and technicians) now predominate in all sections

of the semiconductor industry, as can be seen from the data in Table 1.4.

Table 1.4

Effect of Changes in Technology on the Composition of the Labour Force
(Percentages)

	Electromechanical components	*Integrated Circuits*	*Large-scale integrated circuits*
Engineers and technicians	5	10	30
Qualified workers	60	70	35
Non-qualified workers	15	20	35

Source: H. Correa de Mattos, *Technology and Developing Countries,* International Telecommunication Union, Third World Telecommunication Forum, Geneva: ITU, 1979.

1.22 The highly specialised requirements of the industry have combined with the rapid changes in products and processes to create a demand for teams of scientists, engineers and designers. While increasing use is being made of automatic systems, this has been mainly concentrated on circuit verification and testing; designing elements have remained relatively labour-intensive. The limited supply of design engineers has had two effects: first, to act as a potential brake on the growth of custom products and in favour of standardised products; secondly, to cause very high levels of mobility within the industry, on both a national and an international basis.

1.23 At the national level until the 1970s, this mobility of technical personnel was considered a very significant factor in the creation of most new semiconductor firms, particularly in the United States. It resulted in increased transfers of technology and greater innovation. Subsequently mobility has come to be seen as a constraint on the development of the US industry, as it entered a more mature stage. Japan has seen little such mobility and may consider its relative stability in personnel to be an asset, particularly in R & D.

1.24 At the international level, the increase in demand for skilled personnel has had impacts in both developed and developing countries. The high salaries, mobility and career prospects in the United States have resulted in an important inflow of personnel from Western Europe

(particularly Britain), with consequent problems for the development of this industry in Europe. There has been a similar brain-drain in respect of developing country personnel. As semiconductor industry technology has become more knowledge-intensive, this mobility of labour among firms and countries has also become more important, and its impacts are reflected in the location of production.

1.25 Technology has been a significant determinant of the location of the semiconductor industry. During the 1960s and 1970s US, West European and Japanese producers had set up some 120 plants in almost a score of other countries. Over two-thirds of these facilities belonged to US producers, whose offshore capacity was at one stage estimated at 37 per cent of the American total.[7] In the early years this move to offshore plants was caused by the desire for cost reduction, especially through the use of cheaper labour, and was made possible by the nature of the production processes. The assembly of semiconductors is labour intensive and in the earlier phases of the industry's expansion, assembly represented a significant part of total costs. While much of the move to offshore locations by US firms was related to the expansion of capacity, the motivation of the European and Japanese companies may have been influenced more by the desire to acquire new technology, be closer to end-users and, in Japan's case, to avoid trade frictions. These differing emphases were reflected initially in the tendency for US companies to expand production in developing countries and for European and Japanese companies to locate in other developed countries.

1.26 The changes in technology in semiconductors have, however, resulted in a decrease in the proportion of value added by offshore plants, and a fall in their share of production of the more sophisticated products. The increasing complexity both of products and of processes, and the expansion in vertical integration and inter-firm cooperation, suggest this trend will continue. As the industry has become more dependent on R & D, there has been an increasing trend to locate entire manufacturing processes in the parent country. Production offshore has in general focused increasingly on older-type devices, rather than keeping up with the technical developments of the industry.

1.27 This tendency to concentrate the new processes and products in firms' parent countries has been reinforced by the significant role which governments have played in the industry through procurement, R & D, and investment. Both government procurement and involvement in R & D have been major contributors to technological change.

1.28 Offshore production, particularly in its initial stages, has bestowed substantial economic benefits on some developing countries,

contributing to increased exports and job-creation. However, almost all the semiconductor technologies have characteristics which cause most developing countries difficulty in gaining access to the industry. Particularly important are the high start-up costs; the need for specialist equipment, suppliers and skilled labour; the rapid innovation of technologies; and the possibilities for substitution between production processes. Even the technologically more advanced developing countries (notably the NICs) may have considerable difficulty in keeping abreast of the industry's rapidly moving technological frontier.

Consumer electronics

1.29 The consumer electronics industry includes a wide variety of products of differing degrees of sophistication. It does however exhibit a number of common trends resulting from the application of new technologies. First, there has been a proliferation of new products, based on microelectronics. The rapidly increasing demand for these products has stimulated the renovation and resurgence of what had largely become a mature industry. Secondly, the new technologies have significantly altered the unit cost, content and function of many consumer electronic products. While functions have greatly increased, unit costs/prices have sharply decreased (for example, in business calculators, the price per unit of function decreased from $170 in 1965 to around $5 in 1980).[8] Thirdly, there has been a process of transforming products from discrete devices to components in integrated systems; for example, cash registers have changed from adding machines to interactive data terminals.

1.30 These developments are typical examples of the trend towards convergence in the electronics sector. This has several implications. First, components integration has resulted in a shift in value-added away from final products manufacture towards components and hence components manufacturers. In the case of calculators the cost of components and materials during the electromechanical era had been around one-fifth of the total, but with the introduction of electronics it increased to three-fifths. On the other hand, the cost of labour was reduced from 23 to 5 per cent.[9] Secondly, integration into systems has led producers to move from components production into supplying total systems (with similar implications in costs of entry as those in semiconductors noted above). Thirdly, the need has arisen for communications networks to enable 'systems' to interact. Fourthly, the dynamics of new technologies have drastically reduced the product cycle duration, with a consequential need for increased flexibility of both management and production workers.

1.31 In contrast to the semiconductor industry, consumer electronics has until recently involved a relatively high amount of labour-intensive

assembly work. It therefore offered a relatively easy point of entry for developing countries; the export of consumer products by Asian countries in the 1960s and 1970s expanded at more than 20 per cent annually. While the involvement of TNCs in local assembly was crucial in the early expansion of the industry, a number of developing countries were able to develop a strong local industry in some of the more mature products.

1.32 The emergence of Asian countries as the dominant source of consumer electronics products was the principal feature of the industry during the 1960s and 1970s. Reflecting a competitive advantage based on low labour costs, many other developing countries attempted to follow the same path. Indeed, in certain product categories, new entrants in developing countries may still be able to retrace earlier steps, and by concentrating first on satisfying the domestic market, they can probably do so without external involvement. However, where the intended objective is to export more sophisticated products, a whole new set of difficulties has arisen.

1.33 Again, the situation of Asian developing countries is instructive. Despite a growing local industry, most of the consumer electronics producers in these countries have been heavily dependent on Japanese multinational companies either for know-how or for components. On average the countries imported more than 70 per cent of their ICs, precision component parts and colour TV components from Japan.[10] Such dependence has proved a problem for the producers in these countries as they try to upgrade their product capabilities.

1.34 The changing technologies in consumer electronics have many impacts which are similar to those in the semiconductor industry. The speed of technological development, inadequate technology transfers and increased international competition have all made entry much more expensive and difficult. The introduction of improved products and process automation have tended to erode the developing countries' labour cost advantage. A comparison of the costs of manufacturing electronic devices in Hong Kong and the United States shows that the difference is very much less with semi-automated processes than with manual ones, and is almost negligible with automatic processes[11] (see Table 1.5 overleaf).

1.35 There has been increasing evidence in consumer electronics of the greater use of scale economies to achieve market dominance and of significantly altered investment patterns. Both have accentuated the development of newer consumer electronics products in the major industrial countries. The experience of the NICs, however, suggests that flexibility to exploit changes in demand may enable some developing

Table 1.5

Manufacturing Cost per Electronic Device
(US dollars)

Process	*Hong Kong*	*United States*
Manual	.0248	.0753
Semi-automatic	.0183	.0293
Automatic	.0163	.0178

Source: Rada (1984).

countries to fill a variety of product niches. For example, Hong Kong has moved out of those lines for which demand is sluggish, including table calculators, dictating machines and tape recorders, into those where it is more buoyant, such as portable colour televisions and electronic watches. The decreasing unit prices of semiconductor devices also offer possibilities for introducing new technologies into other consumer products such as toys.

1.36 In general, however, the developing countries' shortages of skilled labour have reinforced the trend for their output of consumer electronic products to be focused on those items whose production processes are technologically mature, rather than on those dependent on the latest technologies.

Computers

1.37 The computer industry also shows a wide range of products with different production structures. These products range from large, very expensive and highly sophisticated mainframes produced by a small number of TNCs, to very small and often simple computers produced by hundreds of small manufacturers. The evolution of the industry reflects its continuing response to the availability of new technology.

1.38 The impact of new technologies, particularly those emanating from the semiconductor industry, has largely affected computers in terms of their speed and cost per unit of operation, and memory capacity. The evolution of the first four 'generations' of computers reflects these changes: first generation, discrete components and hard valve technology; second, discrete components and separate transistors; third, based on integrated circuits; fourth, evolving into large-scale chip integration. The consequential gains in performance and reductions in cost have resulted in a very rapid expansion in world demand, although there have been considerable fluctuations in growth.

1.39 There are two major developments currently working through the computer industry, which further reflect its dependence on new

technologies. The first is the blurring of the traditional lines and roles of computers. The emergence and phenomenal growth of demand for micro-computers has resulted from their cost and performance (with 16 and 32 bit processing capacity, the latter is approaching many mainframe computers). The second (at the opposite end of the scale) is the development of fifth generation machines. These can be divided into two sub-groups, viz. computers involving artificial 'intellegence', and 'super-computers' applying vast processing power to classic number-crunching tasks. It is expected that, in future, super-computers will start to move along a similar price-performance curve to that already taken by other types of computers.

1.40 The key characteristics of the computer industry are the intensifying competition in most product lines and a consequent increasing resort to alliances and partnerships. The latter has, in turn, led to a rapid convergence of component, computer and other information technologies.

1.41 Many producers have been concerned not only with the growing cost of R & D in computer technologies but also with the increasing penetration of the industry by Japanese companies and the entry of the world's dominant computer company—IBM—into new segments of the market, particularly personal computers.[12] Other companies have responded by increased collaboration through what has been described as 'strategic partnering alliances'.[13] In the past a manufacturer usually supplied only one segment of the computer industry, such as software, mainframe or mini-computers. Now these products are converging and customers want to buy entire systems from one supplier. Manufacturers have therefore had to broaden their product lines very rapidly and most have either invested in other companies or bought technology and products from them.

1.42 But if these relatively large (second-tier) companies are now facing problems in maintaining their place in the changing industrial structure resulting largely from responses to new technologies, then the position of smaller companies (and of developing countries) is even more difficult. First, they have to face high capital investments in both R & D and production facilities. Secondly, they are very vulnerable to competition, not least because of their lack of product diversification.

1.43 The full implications of the impact of new technologies on developing countries' computer industries are, however, not yet fully clear. The vast increase in the range of applications of computers has led to a similar expansion of developing countries' demand (particularly for micros), but doubts remain as to their ability to satisfy this demand. While some local suppliers may be assured of advantageous positions

in filling niches left by international suppliers, and may be able to build complete systems from off-the-shelf components, the apparent failure of the Brazilian experiment raises significant doubts. The problems faced in Brazil included the high cost and questionable quality of the locally produced units; the difficulties of Brazilian firms in keeping up with advances in technology and achieving self-sustaining growth, stimulated by indigenous innovation and supported by the expansion of domestic components production; and the aggressive responses of foreign firms barred from what they saw as an extremely lucrative market.

1.44 Another issue is the impact of technology on the developing countries' role as exporters of computers. Developed country manufacturers have turned increasingly to developing countries as a source of low-cost labour for assembling computers (primarily micros) and manufacturing competitively-priced components and peripherals. These initiatives have been undertaken to supply both developed country and local markets, and in the case of the NICs, such as Mexico, Brazil, Singapore and and South Korea, to serve regional markets as well.

1.45 This entry of foreign firms has been accompanied by the emergence of domestic producers of computers, particularly in the NICs. The same is true of production of computer parts and peripherals. For example, the Asian NICs have been able to exploit niches left by some of the major developed country suppliers of parts and peripherals; whereas none of the four biggest developing country producers, viz. Singapore, Hong Kong, South Korea and China (Taiwan), were exporting more than $300 million of these products in 1982, all expect to be exporting more than $1 billion worth in a few years time. China (Taiwan) and South Korea hope to become major suppliers of terminals, monitors and printers. South Korea already has 18 CRT terminal manufacturers with annual production of 306,700 units and nine printer manufacturers producing 23,000 units annually.[14] Singapore aims to become a major supplier of disk drives, while other developing countries, such as Malaysia, have entered the components market.

1.46 It is therefore possible that the combination of sourcing by foreign firms and exporting by domestic firms will lead some developing countries to become significant suppliers in particular segments of the computer industry.

1.47 Yet while there is scope for developing countries to design and produce computers, components and peripherals, by exploiting product niches, there is also evidence that the rapidity of change in technology may be increasing the barriers to entry in a similar manner to that we have observed in the semiconductor industry.

Software

1.48 The impacts of new technologies on the software industry are perhaps less marked than those on other parts of the electronics sector; those which are apparent, however, have a number of characteristics in common.

1.49 The high rate of growth of the software industry, developed through specialised computer service firms as well as hardware producers, has caused changes in operating practices. The increasing complexity of hardware and operating systems, the appearance of sophisticated new software engineering techniques, and the growing requirements of users, have all imposed more demanding conditions on software creators. Software houses now need more complex equipment and more highly-skilled personnel than in the 1970s; and these resources have become very scarce. Since the rate of innovation does not always allow time for employees to learn new skills, software houses are looking to external supplies of labour, while the qualifications they seek are becoming increasingly costly.

1.50 The likelihood of technology gaps emerging among computer service firms now seems greater than in the 1970s when software houses offering custom services had little competition and so were not obliged to keep abreast of the state of the art. But in the 1980s, the software-package phenomenon has compelled software houses to become much more competitive, both at home and abroad. Many houses have responded to the challenge by developing packages themselves. But apart from the technological prerequisites, this strategy implies undertaking substantial development investment for an uncertain return. Packages involve very different costs and risks from traditional custom-made software. They also require much more marketing activity than does custom software: for example, promotional campaigns should cover all potential markets.

1.51 All these factors considerably increase the financial costs of meeting competition in the computer services industry. For most software houses, these costs are a new constraint, prompting them to seek new financial and organisational arrangements. In the United States, where these trends have been taken furthest, there has been a very marked increase in mergers and acquisitions in the industry: there were 87 acquisitions, with a total value of $688 million, in 1980; 118, with a total value of $766 million, in 1981; and 146, with a total value of more than $1 billion, in 1983.[15] Many software houses which have grown rapidly and want to keep their independence have become public companies. But only those with established market positions can raise the necessary finance for this through merger or equity issue. New

enterprises cannot do so, and neither can they hope to borrow from the banks, which are very cautious about financing such entities. The principal remaining source of funds for the entrepreneur is venture capital, which has become very important in some countries, especially the United States.

1.52 New technologies have also had some impact on software productivity (notoriously difficult to measure) through the application of automation to the coding, 'debugging' and testing/development stages. These have proved amenable to change brought about by the use of structural programming, programme generator software, and automated testing. Software production is also being influenced by the move to fifth generation (artificial 'intelligence') computers and by the development of 'firmware', although evidence of the scale of their impact is not yet readily available.

III. CONCLUSION

1.53 These brief reviews of industry groups within the electronics sector show the difficulties inherent in attempting generalisations at the sectoral level of the impacts of new technologies. As well as the rapidity of change in technologies being introduced both from outside the sector and from industries within it, the inter-related nature of the electronics complex makes isolating impacts difficult. However, the distinction which has been drawn between impacts on the semiconductor industry and those on the other parts of the electronics sector may be becoming less apparent. There appears to be some evidence that throughout the sector the impact of new technologies is increasing the advantages of scale, restrictions on access for new entrants, size of establishment costs, and capital needed to support both R & D and marketing. But whilst these characteristics appear to have generally adverse implications for developing countries, other evidence suggests that there are still niches in which producers in these countries may have advantages and through which they can continue to develop their electronics capacities.

NOTES*

1. Rada (1982).
2. These include data processing services; professional (consulting, engineering and custom) services; software products; and integrated turnkey systems.

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

3. Telecommunications are considered in Appendix 3.
4. The somewhat arbitrary division of the electronics sector adopted here is reflected in the lack of any consistent identification in production and trade statistics either of the sector as a whole or of its component parts. There are but few and partial efforts at estimating output, employment, productivity or other indices of the electronics sector, even at the national level. Considerable confusion is also possible because of the changes over time of the 'electronics' components of various subsectors. In particular, there are few statistics on the impact of new technologies in the developing countries (except for the NICs' experience in consumer electronics), and most evidence relates to the results of innovation in the developed countries.
5. Soete and Dosi (1983).
6. Truel (1980).
7. Rada (1982).
8. Hoffman (forthcoming).
9. Rada (1984).
10. J. Clarke and V. Cable, 'The Asian Electronics Industry Looks to the Future', in R. Kaplinsky (ed.) *Comparative Advantage in an Automating World,* IDS Bulletin, March 1982.
11. *Global Economies Information Newsletter* No. 25, October 1982; Rada (1982) p. 10.
12. IBM already has about 70 per cent of the mainframe computer market and about 50 per cent of all computer systems, worldwide.
13. UNIDO, *Microelectronics Monitor,* No. 10/11, September 1984.
14. D. Ernst, 'Automation and the Worldwide Restructuring of the Electronics Industry: Strategic Implications for Developing Countries,' in Hoffman, ed. (1985).
15. J. Bessant, *Technology and Market Trends in the Production and Application of Information Technology:* UNIDO, 1984, IS.438.

Appendix 2

Industrial Applications of Microelectronics: the Textiles, Clothing and Engineering Industries

I. INTRODUCTION

2.1 Besides their use in computers and consumer electronics, microelectronics have several major industrial applications in the form of computer-aided design (CAD), computer-aided manufacturing (CAM) and robots, while there is extensive incorporation of microprocessor control systems into equipment specific to each industry, for example numerically controlled machine tools (NCMTs) in engineering and electronic sewing machines in clothing. Overall, in the developed countries, investments in NCMTs are much larger than in CAD systems, or robots. In the United States, for example, of the $2.9 billion invested in industrial applications in 1981, 65 per cent was in NCMTs, 30 per cent in CAD and only 5 per cent in robots. In Japan, in the same year, investments in NCMTs were three times higher than in robots. For the developing countries, NCMTs probably account for the largest proportion of investments in this area, followed by CAD/CAM, and robots (the latter being almost negligible).

2.2 Very few of the existing 10,000 CAD systems are in developing countries, and those which are have been used mainly for mapping. However, the use of CAD systems in the engineering industry seems to have been growing in these countries, albeit from a very small base. The technology is still mainly restricted to large users, due to the relatively high price of the equipment. Similarly, developing countries, with the exception of a few newly industrialising countries (NICs) (notably Argentina), have made little use of robots. By contrasts, some 31,000 robots had been installed in the industrial countries by 1982,

about 42 per cent in Japan, 20 per cent in the United States and 11 per cent in Germany (F.R.).

2.3 In this appendix we examine the growing use being made, particularly in developed countries, of microelectronics-based equipment in three industries of importance to developing countries—textiles, clothing and engineering. The implications for productivity, employment and international trade were examined in Volume I, Part II, Chapter 1 of this Report.

II. TEXTILES AND CLOTHING

2.4 The textiles and clothing industries have traditionally been associated with the early stages of industrial development. Thus since the 1950s and 1960s production capacity has been set up and steadily expanded in many developing countries, while falling in most developed countries. This has tended to endorse the view that both industries are based on mature, labour-intensive technologies. However, a large number of innovations have occurred in the last 20 years in both industries, especially textiles, culminating in the introduction of microprocessor-based techniques. The following paragraphs briefly review the nature of these technological changes, focusing on the latest generation, and discuss their implications for the textiles and clothing industries of developing countries.

The new technologies[1]

2.5 Essentially the processes involved in producing textiles are designing, fibre preparation, spinning, weaving or knitting, and finishing (including dyeing); making clothes involves designing and pattern making, followed by cutting, sewing and finishing. The new technologies have affected all of these processes, though to differing degrees, as they have the general management of the textile and clothing industries. Much, however, has depended on the extent to which the new techniques have been diffused.

Designing

2.6 CAD techniques offer extensive opportunities for both textile and clothing production. Textile manufacturers have traditionally had to prepare several samples of cloth for their potential customers, which can be a time-consuming task. Now hundreds of examples can be presented to a customer on a computer screen, and only a few are then woven into samples before a final choice is made. Moreover, the

computer has all the information ready for setting the loom for production. There appear to be greater problems in using CAD to depict the drape and fall of material, as is required in clothes designing, though a prototype is reported to have been developed and may be on the market soon. However, once a basic design has been drawn up manually, minor adaptations can be made with the help of a computer, and CAD systems have become important in grading and marker-making activities.

Fibre preparation

2.7 The blending, carding and drawing out of fibres in preparation for spinning have undergone various degrees of mechanisation. Latest equipment is highly automated and can be operated with the use of computers. At the same time, there have been changes in the processing of chemical-based fibres which are not spun before being woven. For example, crimplene can now be textured at a rate of 800 metres a minute—compared to the 50 metres achieved in the 1950s.

Spinning

2.8 The ring-frame spinning machine which was first introduced in the United States in 1830 is still widely used today, though in a much improved form; between 1950 and 1975 the speed of output doubled, while the quality of yarn and reliability of operation also increased. As limits on this equipment were approached, open-ended spinning machines were developed which operate at speeds four times as fast as ring-frame spinners, partly because they allow the integration of three previously separate processes (roving, spinning and winding). Although fabrics woven from open-end spun yarns are reported to be inferior to those from ring-spun yarns, this technique now accounts for more than 15 per cent of all yarns produced in the United States, compared to only 3 per cent in 1975.

Weaving

2.9 In weaving, the major innovation since the mid-1950s has been the development of the shuttleless (flat) loom, of which there are four types—looms with gripper or dummy shuttles, looms with mechanically operated gripper arms, looms with water or air jets, and looms that mechanically propel the filling. Shuttleless looms are estimated to account for around half the looms now in use in Europe. They have the advantage of requiring less power and space and having lower sound levels than the automated conventional jacquard or dobby power looms, as well as being faster, particularly when multicolour fabrics are being produced. The more recent use of multiphase weaving has

allowed up to 600 picks per minute, as against 180 on high-speed conventional looms, with weft insertion rates rising from 400 metres per minute to 1,840 metres. Further improvements in productivity have been achieved, of up to 170 metres per man hour, with the use of microelectronics to control the looms and to monitor the quality of the cloth produced.

Knitting

2.10 Since the 1960s changes in knitting technology have made it an increasingly popular way of producing cloth; labour requirements per unit of output are to 30 times lower than for weaving, while in a given time even a fast shuttleless loom produces only 12 per cent as much fabric as a modern circular weft knitting machine. Four other factors have been important. Costs have fallen as a result of declining prices of man-made fibres which are extensively used in high-speed knitting. There are also savings to be made for products where the fabric and garment stages can be combined in a single process (as in the production of hosiery or T-shirts). Knitting machines are very flexible, with most able to produce a wide range of products, which makes them particularly suitable for use in small units. Finally, the range of designs has been greatly extended (and down-time reduced) by the use of mini-computer control systems, integrating CAD with electronic selection of the needles. However, continued consumer demand for woven fabrics of natural fibres, which are less suitable for knitting, has restricted the substitution of knitting for weaving.

Finishing, dyeing and printing

2.11 Textile finishing has become more automated, in the most advanced textile firms, than perhaps any other process, thanks largely to the incorporation of automatic control and computer systems, which have allowed continuous processing and quality improvements. Since the early 1970s computer controlled sensors have been developed for use in cloth dyeing. By monitoring and regulating the temperature and dye-bath strength, for example, they are able to improve the colour consistency of different pieces of cloth. More recent advances in colour physics combined with microelectronics have led to the use of computer-based spectrophotometers, which can define shades numerically, allowing colours to be repeated accurately, and also scan a piece of cloth (or garment) for colour consistency. They are being used primarily by manufacturers supplying high-quality fashions, for whom any colour mismatching can lead to large financial losses. Computers are also used to control continuous finishing, while computer-controlled lasers can be used to detect faults in cloth before it is finished, scanning an average of 270 metres per minute compared to the 50 metres achieved

with manual techniques. Further modifications are likely as manufacturers seek to reduce the hot water needed for dyeing, thereby cutting energy costs.

2.12 There have also been several changes in printing technology, with the development of roller, automated flat bed, and automatic rotary screen printing methods; in the latter case output has progressed from 500 to 2,000 metres per hour, while a large range of colour combinations is possible.

Pattern making and cutting

2.13 Once a garment has been designed, CAD may be used to calculate different sizings and plan optimal lay-out (minimizing cloth wastage). This information can then be relayed directly to the cloth cutting equipment, which most recently includes CNC laser beams, water jets and steel knives that can be operated continuously, cutting up to 300 layers at one time. Together, these new techniques have helped to reduce the time to lay out and cut a suit, for example, from an hour to four minutes, and also to reduce the need for skilled workers.

Sewing

2.14 In comparison with other processes there has been relatively little technological progress in the sewing stage of garment production, though there are signs that a revolution in production techniques is about to take place. While embroidery has been essentially automated, sewing machine speeds have increased by 50 per cent on average in the last 20 years. In particular, microelectronically-controlled dedicated machines, which perform all the tasks associated with one operation, for example collar assembly, have led to productivity increases in these tasks of up to 80 per cent, and operator-programmable multipurpose machines have raised productivity by up to 46 per cent. The use of synthetic fibres has led to some garments being fused together with high frequency sound waves (ultrasonic sewing) at a much faster rate than if they had been sewn with thread. But the impact on overall labour productivity has been restricted by the large amount of time which has to be spent loading and unloading material (about 75 per cent of a machine operator's time), arising from the numerous operations involved in the construction of a garment (for example 40 for a pair of trousers and 80 for a jacket). Other technological changes have been made in an attempt to cut down the time involved in these operations. One is the introduction of a microprocessor-controlled arm that can grasp cloth and move it through the sewing machine, repeating operations after they have been performed once by hand, though so far this technique has been restricted to fairly simple tasks. Another is

the use of robots in automatic transfer lines, to pick up pieces of cloth from a bundle, lay them ready to be sewn in a correct sequence, remove the finished work, and take it on to the next machinist for further processing. With more developments along these lines already underway, it is possible to envisage a fully automated clothing factory emerging in the near future; indeed the Japanese plan to produce prototypes of such a flexible manufacturing system by 1987 and to start commercial production of the technology by 1989, while the EEC is spending some $26 million in similar research.

Finishing

2.15 This is still one of the more labour-intensive stages of garments production, with the continued extensive use of electric irons and steam presses. First generation innovations have included the continuous pressing of separate parts of a garment using a steaming balloon, and equipment incorporating microprocessor-controlled pressing variables (steam, temperature, etc) which remove a high proportion of the skill previously involved in pressing, at a capital cost of $30,000–$200,000.

General management

2.16 Many textiles and clothing firms have also sought to raise their production and productivity by using computers to monitor and improve the organisation of their work processes and to operate automated materials handling and inventory control systems.

Technology diffusion

2.17 The impact of these new technologies on the world's textiles and clothing industries will depend on their rate of diffusion. The limited evidence available suggests that diffusion of microelectronics-based technologies has been fairly slow (probably more so than in most other industries), being restricted for the most part to large firms in developed countries, though there are exceptions such as leading firms in Hong Kong, South Korea and Singapore. A recent survey of the industries in Germany (FR), France and the United Kingdom, for example, found that between 20 and 40 per cent of textiles and clothing factories used microelectronics, a lower proportion than for any other manufacturing industry.[2] While this may partly reflect the technological problems of automating garment-making processes (and the fact that there is no scope for incorporating microelectronics in textiles or clothing as products), it also reflects the relatively low levels of investment in both industries. This has meant that the technologies most commonly used in developed countries' textiles and clothing industries are well behind the 'state of the art' technologies, let alone the frontier,

microelectronics-based innovations. According to one estimate average productivity could be improved by as much as 33 per cent if all firms used the former, while even greater gains would be made with the latter.[3]

2.18 The newer technologies are expensive and usually require long production runs (and low down-times) for any productivity gains to be realised. A major barrier to their uptake has been the fragmented structure of the textiles and clothing industries, and even in the United States two-thirds of the output comes from firms with less than 50 workers. In the clothing industry, CAD systems which cost $0.3 million to $0.6 million in the United States (and much more in Europe) are calculated to require an annual company turnover of at least $20 million to be viable.[4] About half the firms of this size are reported to have invested in CAD, but they account for barely one-fifth of the clothing output in developed countries. The cost of automated cutters is somewhat higher ($0.5 million, or $1 million if combined with CAD), in addition to which there are associated costs arising from the need to reorganise production to allow centralised cutting on a 24 hour basis, and this has restricted their use to the larger firms. Nevertheless, by the end of 1982 there were at least 700 CAD systems and 300 automated cutters in use worldwide. With increasing competition between CAD suppliers lowering prices, and the establishment of time-sharing bureaux making CAD equipment accessible to firms with sales of less than $50 million, the number of systems is likely to grow fairly rapidly. Similarly, dedicated items of equipment costing $15,000 to $40,000, such as automatic belt-looping machines or pocket hemmers, need new parts costing some $4,000 to be installed every time a style is changed, and this can only be justified for long production runs. Programmable sewing machines, on the other hand, which cost $5,000 to $8,000, are more suited to small firms, being both less expensive and more flexible, though most managers of small family-run enterprises are still likely to prefer conventional machines costing some $600 as long as market conditions remain uncertain. On average, however, even in larger firms a survey found that only 5 per cent of sewing machines used had microelectronic controls.[5] But in the medium term the pace of technological change may increase if more technologies appropriate to the smaller firms are developed, or if the structure of the two industries becomes more concentrated, or if competition from developing countries grows following relaxation of the Multifibre Arrangement (MFA) which governs their exports of textiles and clothing.

2.19 In developing countries the introduction of 'state of the art' technologies, let alone 'frontier' microelectronics-based technologies, faces even greater barriers. These operate at several levels. First, there are a number of technical barriers. For example, local yarn supplies

may not be of sufficiently high quality or energy supplies sufficiently reliable to use automatic looms. Secondly, there are often trade barriers restricting imports of new equipment—the result of balance of payments constraints, or even imposed by developing country governments to promote their own textile machinery industries. India has been one such example, though recently the Government relaxed its controls on loom imports in order to boost the competitiveness of exports.

2.20 Thirdly, and most important, there are economic barriers. Many new technologies are less appropriate for the textiles and clothing industries in developing countries, which are highly fragmented and where wages are comparatively low, than for those in developed countries. Even where these technologies appear to individual entrepreneurs to be economically efficient, they may not be for society as a whole. Thus some governments have deterred investment in new equipment, either directly by restricting modernisation in order to protect employment, or indirectly by limiting the capacity of firms in the organised sector in order to protect small producers in the informal sector. For example, in India the restriction on the size of spinning mills has meant that the economies of scale needed to justify some of the newer technologies have not been present. Weaving mills have not only had their capacity controlled but also the speed at which they could replace their plain looms with automatic ones. Thus over half of the spinning and weaving equipment in India is estimated to be over 20 years old and much of it over 40 years. Only 20 per cent of looms in the organised sector are automated and most of these are first generation conventional automatic shuttle looms—less than one per cent are shuttleless. Amongst other major developing country textile exporters the share of automated looms varies considerably, from 45 per cent in Brazil (though only 3 per cent are shuttleless), 78 per cent in Egypt, and 81 per cent in Pakistan, to 100 per cent in Hong Kong—reflecting major differences in economic factors and government policies.

2.21 The Hong Kong textiles and clothing industries are probably the most technologically advanced of all developing countries. Restriction of its exports under the MFA and increased competition from lower wage producers have forced it to move into high value, high quality goods which invariably has involved greater use of high-tech equipment. Thus most mill machinery now consists of open-end rotors and shuttleless looms, and there has been investment in computer-controlled cutters in a number of garment factories. In South Korea the government has subsidised the modernisation of the country's textile sector in a bid to increase automated weaving from 35 to 50 per cent and to replace 30 per cent of its weaving and spinning equipment estimated to be obsolete. Finally, a similar policy of promoting automation is being followed in

Singapore, as a means of boosting garment-makers' reliability and quality control.

2.22 In general the limited data available suggest that there has been little use of microelectronics-based technology in developing country clothing industries. Major suppliers have sold less than a dozen CAD units to the NICs, though in the medium term their volume of output would appear to justify an additional 30 to 40 units in Asia alone. Similarly there has been little diffusion as yet of automated sewing machines, with only a few of the larger Asian exporters and the Latin American producers for the domestic market buying dedicated units, and perhaps a larger number (20–30 units) of programmable machines being sold each year.[6]

II. ENGINEERING

2.23 In the last twenty years the engineering industry in developed countries has been affected by the introduction of new, essentially microelectronics-based, technologies perhaps more than any industry. Whereas for others the predominant use of microelectronics has been to alter processes, for engineering it has altered both products and processes.[7] Within engineering some branches, notably electrical and instrument making, have experienced more product innovations than others, such as mechanical engineering, vehicles and other metal goods; the latter have, however, been involved in extensive process innovations. Changes in some branches have also affected others. For example the substitution of electronic for electromechanical components in electrical engineering has reduced its purchases from the mechanical engineering branch.

2.24 At the same time there have been substantial, though fundamentally different, developments in the engineering industry in developing countries. Here the emphasis has been on expanding the range of products as well as updating the processes used, predominantly through the use of imported and relatively mature technologies with some indigenous modifications. As a result, total engineering output has increased and a number of the technologically more advanced countries have emerged as large exporters of engineering goods. One of the main concerns of many developing countries is whether the new technologies offer them further opportunities to expand their engineering output, and if so, what the relative costs and benefits are, taking into account the impact on other industries. We deal with this next.

The new technologies

2.25 By far the most extensive types of new technology in engineering are those based on microelectronics, though changes arising from

Table 2.1

Applications of Information Technology in Engineering Processes

Activity	*Application*
Information processing and handling	
Administration: i.e. accounting, customer order handling	Computers for record keeping, analysing information
R & D	Computers for model building, complex calculations
Design and draughting	CAD
Production planning, inventory control	Computers for scheduling
Materials processing and handling	
Processing	Computer controlled conveyors and other machines, robots
Testing	Automated testing equipment
Output	Automatic packaging, computer controlled warehousing and distribution
Combined information and materials processing and handling	
Manufacturing	Linking computer controlled machines with a common data base—known as direct numerical control or flexible machining/ engineering systems
Inventory/distribution	Automated warehousing—linking computer controlled machinery with computerised information on inventory and distribution
Manufacturing/design	Integrated manufacturing system or CAD/CAM—linking CAD and computer controlled machinery with a common data base
Fully integrated control of materials and information	Integrated business system—CAD/CAM linked to all systems for controlling marketing, buying, production planning, administration

Source: Adapted from Wilson (1984) p. 17.

Table 2.2

Recent Technological Changes in the Japanese Automobile Industry

Product technology	*Parts or processes replaced*
—New vehicle design, e.g. shift to front wheel drive	Propeller shaft, differential gear
—New parts, e.g. digital display meters, disc-brakes, electronic accessories	Analogue display meters, drum-brakes
Production technology	
—New materials, e.g. plastics, ceramics	Steel stamped parts
—Processing of more complex shapes and/or higher quality parts, e.g. with moulding, NC machine tools	Smaller stamped or machined parts, hand-operated or automatic machines
—Improvement of work environment, need for more flexible equipment, e.g. with robots	Manual work, mechanical automation
Organisation technology	
—Includes use of automatic loaders/unloaders, transfer machine lines, CAD/CAM, and office automation, and also the 'just-in-time' system	Manual work, inventory control and management

Source: Adapted from Watanabe (1984) p. 11.

technologies for producing new materials and renewable energy sources are also taking place. The wide range of applications of computers and microprocessors, from the processing and handling of information (including design) to the control of materials processing, and even fully integrated business systems, is shown in Table 2.1 above; Table 2.2 lists the numerous technological changes in the Japanese car industry. CAD is the principal automation technology in the design phase of the production process; besides applications in engineering, it is used widely in other industries (as discussed above in Appendix 1 on microelectronics). So, too, is CNC technology, which is extensively used in manufacturing although originally developed for machine tools.

2.26 CAD has had a profound impact on engineering designs. It was first used in the late 1950s by the aerospace and defence industries, only being introduced to the electronics sector in the early 1970s and mechanical engineering after 1975. Its interactive graphics capacity

means that all features of a product or part can be graphically represented in three dimensions, allowing the effect of a change in any parameter to be calculated instantly and a multicomponent product to be 'exploded' to see how the parts fit together. Not only are design times drastically reduced, but working drawings can be produced and parts lists prepared more quickly and accurately than before. CAD also encourages the automation of subsequent manufacturing stages (whether by CAM or some other form) as the reduction of all design information to electronic signals, which occurs in CAD, means that downstream machinery equipped to receive electronically transmitted instructions can be directed and controlled with minimum human intervention.

2.27 The diversity of CAD technology has led to a rapid growth in its use, with global sales rising from $80 million in 1976 to $1 billion in 1980 and $5 billion forecast for 1985; a 40 per cent annual growth is projected during the 1980s for the OECD market alone. Global installations of CAD, of 10,000 in 1982, are expected to grow to 27,000 by 1986; about 50 per cent of them will be in the United States, 35 per cent in Western Europe and less than 0.5 per cent in developing countries. In the developed countries, CAD is predominantly used in the electronics, aerospace and automotive industries,[8] but it is increasingly being found in mechanical engineering, architecture, clothing and construction. The limited data available for developing countries suggest CAD is being used primarily in the engineering sector, for example in component and automobile manufacturing, metal works, and consultant engineering, as well as in shipbuilding.

2.28 NCMTs, which drill, grind, etc according to instructions numerically recorded on magnetic or perforated tapes or cards, were introduced in the early 1950s. The control hardware was expensive and bulky, which limited its use and ensured the continued dominance of conventional machine tools. The incorporation of computers in NCMTs to produce CNC machine tools has challenged conventional tools by creating an increasingly versatile, accurate and cheap piece of equipment, which can combine previously discrete operations into one machine. This has radical implications for the organisation of production. CNC tools may be linked directly to CAD systems, leading to the integration of design and manufacturing, while the use of a central computer to control simultaneously a number of CNC machines allows a continuous production process instead of batch production. In some cases up to 100 machine tools incorporating micro-computers have been directly controlled by a single mainframe computer. This allows a two way flow of information, with the mainframe transmitting instructions to the individual tools via their micro-computers, which in turn transmit back information on the status, volume and quality of production to

the mainframe, providing managers with an instant overall picture of the production process. There are also important implications for producers of conventional equipment—as outlined in Volume I, Part II, Chapter 1. For example CNC lathes have been substituted for the engine lathes which form the bulk of NIC lathe exports, rather than for other types of conventional lathes.

2.29 These factors have led to a rapid growth in the use of CNC equipment, and their share in the production of all metal cutting machine tools in six OECD countries (United States, Japan, Germany (FR), France, Italy and United Kingdom) rose from 25 per cent in 1976 to 41 per cent in 1982. The bulk of CNC tools in Japan and the United States are used in the general machinery sector, after which transport equipment and electrical machinery are the most important. In comparison the demand for CNC machine tools in developing countries is still small although it is growing, particularly in the NICs, as Table 2.3 shows. Capital goods firms appear to be the leading users, with CNC tools helping to produce turbines, pumps, valves, oil equipment, agricultural machinery, hydroelectric equipment, automobile components and so on.

Table 2.3

Production of and Demand for CNC Lathes in Selected Countries

Country	*Production (units)*	Demand *(units)*	*CNC lathes as % of total lathe investment*
Argentina	10–15 (1981)	60–65 (1981)	38 of all imported lathes (1978–82)
Brazil	36 (1980)	85 (1980)	—
India	4 (1981)	33 (1980)	—
South Korea	222 (1982)	100–125 (1981)	2.4 (1977–78) 34 (1981–82)
China (Taiwan)	174 (1981)	123 (1981)	7 (1977–78) 20 (1981–82)

Sources: Jacobsson, 'Technical Change and Industrial Policy: The Case of CNC Lathes in Argentina, Korea, and Taiwan', in Hoffman, ed. (1985) and Chudnovsky, *The Diffusion of Electronics Technology in Developing Countries' Capital Goods Sector: The Argentinian Case* (CET/IPAL Report, 1984).

2.30 The use of robots, which began in the late 1960s, accelerated in the late 1970s as a result of major technical improvements (Table 2.4). In absolute terms the largest user is Japan followed by the United States, Germany (FR) and Sweden, though as a proportion of manufacturing employees the ranking is somewhat different as the table shows. The main area of application is vehicle production, where there are four major robot types: 'intelligent' robots (mainly used for assembly), numerically controlled robots (assembly and machining), play-back robots (arc- and spot-welding) and fixed sequence robots (loading and unloading). While expansion in the range of activities of robots is likely to increase their number in other industries, particularly in electrical and mechanical engineering, the rate of installation is expected to grow more slowly than in the vehicle industry.

2.31 Linking CNC tools with some form of materials handling system (for example a robot which can transfer workpieces between tools) leads to the formation of an automated manufacturing cell, while the linking of cells via an automated transfer line controlled by a computer hierarchy leads to what is known as a *flexible manufacturing system* (FMS). The considerable costs and difficulties involved in FMS have restricted their number in the OECD to about 150, incorporating some 1,200 CNC machine tools, primarily in factories producing vehicles, machine tools and construction machinery (see Table 2.5 on page 33).

Diffusion in developing countries

2.32 While there are several reasons for the adoption of these new engineering technologies—to improve the quality of products, to alter their nature, and to increase factor productivity (as discussed in Volume I, Part II, Chapter 1 of this Report)—their diffusion in developing countries has been relatively limited. One factor has been the initial cost of the equipment, which ranges from about $20,000 for a robot to millions of dollars for a complete FMS. However, with advances in both electronics technology and the structure of the machines, the cost of some new types of engineering equipment has fallen to below the price of conventional equipment. For example, an FMS for the production of 50,000 tractor components annually may cost $18 million compared to a dedicated transfer line costing $28 million, while an FMS for truck axles may cost the same as a conventional system with a similar capacity but have the advantage of virtually eliminating set-up costs and occupying a quarter of the floor space.[9] In other instances, such as Japanese lathes, the price differential between CNC and conventional machine tools fell from 11:1 to 4:1 between 1970 and 1981,[10] while the price of the average CAD system in 1980, at $300,000, was even in nominal terms a tenth of that of the first system developed in the 1960s.[11] Taking into account the shorter payback period, new

Table 2.4

Population of Robots[a]

	1974	1978	1980	1981	1982	1985[b]	1990[b]	Robots per 10,000 employed in manufacturing 1971	1981
Japan	1,500	3,000	6,000	9,500	13,000	27,000	67,000	1.9	13.0
United States	1,200	2,500	3,500	4,500	6,250	15,000	56,000	0.8	4.0
Germany (FR)	130	450	1,200	2,300	3,500	8,800	27,000	0.4	4.6
Sweden	85	800	1,133	1,700	1,300[c]	4,100	8,300	1.3	29.9
United Kingdom	50	125	371	713	1,152	2,700	10,000	0.1	1.2
France	30	—	580	790	950	2,100	6,500	0.1	1.9

Note: Data based on a narrow definition of robots.

[a] Accurate data on the world population are not available, but the following estimates are indicative: 1980—13,700; 1981-22,000; 1982-31,000.

[b] Forecast.

[c] Data revised downward as a result of definitional changes.

Sources: UN Economic Commission for Europe (1985) p. 42, and UNIDO, *Microelectronics Monitor*, No. 10/11, April-September 1984.

Table 2.5

Final Products Incorporating Parts Manufactured by FMS in OECD Countries

Final product	*Number of FMS*	*per cent*
Automobiles and trucks	27	21
Machine tools	22	17
Tractors and construction machinery	18	14
Aerospace	9	7
Diesel engines	6	5
Electric motors	6	5
Pumps, valves and compressors	6	5
Hand tools, electric tools, etc.	5	4
Railway equipment	4	3
Office machinery	4	3
Others	20	16
Total	127	100

Source: Edquist and Jacobsson (1984).

equipment now appears often cheaper than its conventional equivalent; for example it may take no more than two years to pay off a robotic unit operating two shifts, or two and a half years for an FMS. A British company producing aircraft components found that inventory savings alone were sufficient to pay off its £1 million investment in computer-controlled machinery centres.

2.33 As well as these direct costs, however, the cost of complementary investment in non-microelectronic advanced technologies needs to be included. Generally it seems that the large investments involved, coupled with considerable ignorance about their likely benefits and a reluctance to take risks (especially during a recession), have delayed their introduction in several enterprises, even in developed countries, let alone developing ones.

2.34 Besides cost, an important factor restricting the diffusion of new technologies is the higher (and increasing) minimum efficient scale of production of many of them compared with conventional equipment. Although the flexibility of CNC tools, CAD and, to a lesser extent, FMS, means that they can be used to produce small batches economically—for example, lots of 20 to 100 workpieces in Japan[12]—there are certain levels of aggregate output below which their use is not economical. For robots to be justified in Sweden it was found that

batch runs had to be of more than 10,000 pieces, whereas for CNC tools the batch could be less than 1,000 and annual production above 100,000.[13] Put another way, one CNC tool may substitute for between two and five non-CNC tools. There is, however, some variation between countries, reflecting the different types of new technology in use. Thus in Japan, where CNC tools tend to be smaller and simpler, two-thirds of those sold in 1981 were bought by small- and medium-sized firms—26 per cent by firms with less than 30 employees.[14] In contrast, in the United States two-thirds of CNC tools were being used by plants with more than 100 workers. In the case of CAD, systems based on mini-computers are most profitable if used by more than ten designers, while a mainframe computer can take more than twenty.

2.35 Another factor is the externalities to be gained from the use of several CNC machines as part of a system, compared to their use separately. As well as lower capital-output ratios, indirect costs may be reduced—between six and eight machines are needed to occupy fully a programmer and setter while a maintenance engineer can cope with as many as 15–30 such machines.[15]

2.36 These minimum efficient levels of production constitute an effective barrier to the use of newer technologies by smaller workshops in developing countries, unless they are subsidised, or are able to increase the volume of their output. This in turn will depend partly on the relation between the size of the domestic market and the minimum efficient scale; although exports are always possible, a large domestic market reduces the risk of upgrading production methods and allows products to be proven before export.

2.37 Finally, the need for a minimum level of infrastructure should be mentioned: not only for training design engineers and other skilled personnel, but also for guaranteeing stable electricity supplies. If the electricity voltage falls by 15 per cent or more, as is frequently the case in some developing countries, then CNC machine tools cease to function.

2.38 A major issue is the degree of substitutability between new and mature technologies, and how quickly the former are diffused at the expense of the latter. In the short term it seems that conventional equipment will continue to command an important (though shrinking) share of the market for engineering goods, with sales falling in absolute terms in the developed country markets but rising elsewhere. Developing country exports may be sustained, however, if developed country producers shift production of conventional equipment to developing countries, so that they themselves can specialise in high-tech tools, as major Japanese machine-tool builders have been doing.[16] The question

then arises as to whether developing countries will be able to produce and export high-tech equipment competitively. As suggested earlier, there are a number of barriers to the market which only some of the NICs are likely to overcome. One is the increasingly large scale of production needed to be competitive: in some cases scale may be more important than wage levels, as the share of labour in total costs is falling. Another is the need for domestic capability in electronics design and engineering, servo-techniques, and R & D. A third is the growing links between producers and users of sophisticated equipment which requires the support of an international marketing and after-sales network.

2.39 In conclusion it seems that the new engineering technologies have important implications for the organisation of production and employment in the developed countries' industries. In particular the use of computer-based design and machine tools has allowed continuous production processes to replace batch production in many cases. Associated with this has been increased labour productivity, and substantial capital savings (working and fixed), though initial capital outlays have risen with larger minimum efficient plant sizes. These changes appear, in the first instance, to have most relevance for the more technologically advanced developing countries. Those currently producing conventional machine tools will find their export markets are restricted unless they are able to incorporate some microelectronics into their products. Exporters of other engineering goods may also find their competitiveness eroded by the new production methods, though there is little evidence of this as yet. But some of the new equipment may help in the development of engineering industries in the less technologically advanced developing countries. For example, both CAD and CNC tools could help to reduce the skill constraint, and at an increasingly affordable price. However there is still a minimum level of skills needed for the operation of this equipment, and a minimum level of operation, which would seem to preclude its use spreading to the smaller developing countries in the near future.

NOTES*

1. This section draws on: V. Cable and B. Baker, *World Textile Trade and Production Trends*, EIU Special Report No. 152, London, 1983; OECD, *Textile and Clothing Industries*, Paris, 1983; and K. Hoffman, 'Clothing, Chips and Competitive Advantage: The

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

Impact of Microelectronics on Trade and Production in the Garment Industry', in Hoffman, ed. (1985).

2. Policy Studies Institute (1985).
3. Hoffman and Rush (1980) p. 86.
4. Hoffman, op. cit., in Hoffman, ed. (1985) p. 377.
5. Ibid., p. 379.
6. Ibid., p. 388.
7. For example, Northcott and Rogers (1984) p. 6, show that 30 per cent of mechanical engineering factories in the United Kingdom and 50 per cent of electrical engineering factories use microelectronics in their products while in processes the respective figures are 45 per cent and 50 per cent.
8. In the United Kingdom a third of all establishments using CAD in 1981 were in the electronics sector. (E. Arnold and P. Senker, *Designing the Future: The Implications of CAD Interactive Graphics for Employment and Skills in British Engineering Industry,* mimeo, SPRU, University of Sussex, UK, 1982).
9. Hoffman (forthcoming).
10. Watanabe (1983) p. 27.
11. Kaplinsky (1982) p. 41.
12. Watanabe (1983) p. 9.
13. Jacobsson (1983) p. 153.
14. Watanabe (1983) p. 22.
15. Ibid., p. 67.
16. Ibid., p. 73.

Appendix 3

Information Technology and the Service Sector

I. OVERVIEW

3.1 Services are the most important single sector of the economy in both developed and developing countries, and by 1980 their share of GDP had reached almost 60 per cent in developed market economy countries and 45 per cent in developing countries; even in low-income countries services contributed 40 per cent of GDP. In all categories of country the proportion is an increasing one. The sector accounts for an even larger share of employment in many countries (70 per cent in the United States, for example, compared to 64 per cent of GDP) and for the majority of new jobs created in the last couple of decades (over 80 per cent of those created in Canada, for example, during the ten years to 1979). This reflects the relative labour intensity of most services, and has led some critics to observe that the growth of the sector is constraining overall economic growth. This is somewhat doubtful, however, as data show that even in the late 1970s, value-added per person in manufacturing was for several countries not much higher than in services, while for a number of others, including the United Kingdom and Singapore, it was slightly lower.[1] Subsequently it is likely that the rapid change in technologies in some leading service industries in developed countries has raised labour productivity levels substantially. The issue which we address here, however, is how far developing countries will be able to take advantage of these new technologies and what the effects on their economies are likely to be.

3.2 The most pervasive new technology being applied to services is the so-called 'information technology'. This is based on the digitalisation of data, which can then be processed by microelectronics equipment such as electronic typewriters and word processors, automated teller

machines, point of sale terminals, optical character recognition systems, business computer systems, electronic mail and facsimile machines, viewdata and videotex systems, and miscellaneous computer systems. Such equipment is being used increasingly in telecommunications, banking, insurance, engineering and other technical information services, some public services and even retailing and wholesaling. It also has important, but perhaps less widespread, implications for other service industries, such as social services (health care and education in particular), public utilities, tourism, transport and construction. Other changes in technology—for example the use of fibre-optics instead of copper wire in telecommunications—are also occurring, but overall these appear to be rather less significant and so are considered here only briefly.[2]

3.3 Information technology is affecting service industries in a variety of ways, some of which are apparent from the following examples. The use of this group of technologies is:

—*improving the quality of existing services.* For example, computerised networks linked by telecommunications systems allow consumers to have faster access to more reliable information. Such data can range from, say, details of potential suppliers of agricultural inputs or second-hand construction equipment, to confirmation of bank balances or hotel bookings;

—*creating new services.* Banks, for example, are now able to offer clients new corporate management systems which help them to increase returns on their financial assets;

—*raising labour productivity.* Again using banks as an example, automation has allowed the same quantum of service to be provided by a lower number of workers and has thus led to employment displacement. Instances include automated teller machines replacing bank tellers, and automated bank clearing systems replacing clerks and messengers;

—*increasing capital intensity.* Much of the new technology involves substantial capital investment in hardware (input/output terminals, processing equipment and network facilities) and software. However, once a network is in place, the marginal cost of opening another terminal in a new location is low;

—*increasing economies of scale.* The large sums involved in installing information technologies have led to increases in the minimum scales for many types of operation to be undertaken efficiently. This is particularly marked in telecommunications, banking, and insurance. Though there are some instances of scale economies being lowered, on balance the increasing use of information technology is likely to reinforce present trends towards greater concentration in these industries;

—*creating new economic structures.* Information technology is not only affecting the structure of service industries, it is also blurring the division between them and the rest of the economy. The economies of scale involved mean that once a retail company, for example, has a computer terminal linked to an external information network, there is only a low marginal cost in using that terminal to provide services, such as travel or finance, which are unrelated to its original activity. In addition, the application of information technology to non-service sectors, and the resulting increase in the service content of goods, is blurring the division between different sectors of the economy. For example, in the United States 10 per cent of value-added in agriculture comes from services, as does more than 20 per cent of that added in minerals and manufacturing;

—*improving productivity in the rest of the economy.* The increased use of information technology in producer services, such as public administration and banking, as well as in general business management (monitoring production, stock levels, marketing, etc) should raise productivity in the non-service sectors of the economy;

—*increasing the tradeability of services.* Traditionally, the nature of most services has meant that only a very low proportion of the total has entered international trade—8 per cent in 1980 compared to 45 per cent of world agricultural output and 55 per cent of mining and manufacturing. But the new ways of handling information, coupled with improvements in telecommunications (satellite transmission, digital networks) have increased the tradeability of many services. For example, banking services or an entire library can now be transported from a terminal in one country to a terminal in another. Developed countries (notably the United States) see tremendous potential for their exports of services now that the natural trade barriers have been overcome, and in GATT and other fora these countries are putting pressure on developing countries to remove their controls on imports of services. Whether developing countries are able to benefit, either as consumers or as exporters, from this increasing internationalisation of services in a market dominated by multinational companies, is discussed further below; and

—*affecting international competition in goods.* The increasingly widespread use of information technology by developed country manufacturing and other non-service industries, through helping to raise efficiency, is benefiting their international competitiveness. In particular, improved access to data about world markets and better communications with customers can improve export performance, making it more difficult for developing countries to compete. On the other hand, the ability of transnational corporations (TNCs)

to extend greater control over their global operations might encourage them to increase their involvement in developing country export activities.

3.4 The main technological advances in four major service industries—telecommunications, banking, insurance, and tourism—together with the chief elements of office automation, are considered below. (A more detailed examination of the impact of services on employment, trade and development was undertaken in Volume I, Part II, Chapter 1 of this Report.)

II. MAJOR SERVICE INDUSTRIES

Telecommunications

3.5 The ability of new technologies to digitalise speech, numbers and graphics is leading to a revolution in the range of services offered by telecommunications agencies in most developed and some developing countries. Parallel changes in communications hardware mean that the speed of these services is being steadily increased while costs are falling. Four developments in hardware are particularly important.

3.6 The first is the replacement of mechanical cross-bar and hybrid electro-mechanical analogue switching gear with electronic *digital switching*, which is cheaper, can be centrally controlled by a computer, and allows an increase in the capacity of automatic exchanges, as well as a broader range of services. The second is the use of *fibre-optic cables*, which not only have a cost and capacity advantage over traditional (copper) cables, but also can be hung alongside electricity wires without any problems of feedback. The third is the increasing use of *satellites* for direct telephone, telex and television links nationally and internationally. Finally, there is the use of *microwave* air frequencies in radio-relay systems for subscriber trunk dialling in some countries and, with the help of microchip technology, for cellular radio mobile phones.

3.7 Despite the large costs involved, several developing countries are updating their equipment with these new technologies, in recognition of the key role which telecommunications can play in their economies. For example, the Malaysian Government has increased development expenditure on telecommunications to M$3 billion (US$1.3 billion) over 1981–85 at a time when spending on agriculture, education, health, and housing was static or falling. This is in recognition of the importance of telecommunications to the country's modernisation and to Kuala

Lumpur's future as a regional financial centre. In Singapore, spending on fibre-optic cables, digital exchange equipment, etc. and new services, is to reach US$1.5 billion over the five years to 1990. The bulk of the equipment has to be imported, though some countries (for example, South Korea, India) are producing digital switching gear. Some smaller-scale technologies are being developed in an attempt to reduce the financial problems. For example, amateur radio operators in the United Kingdom, Canada and the United States developed a small low-flying satellite with a micro-computer and an off-the-shelf transceiver in a ground unit costing some $10,000. This provides a cheap storage and forward messaging system, and if linked to a technical information service it could make information available to governments and others, with a 24 hour turn-around and at a relatively low cost.

3.8 Besides traditional voice-to-voice communication, many telecommunications networks now offer several other services. These include: *teletex*, which is claimed in Singapore to be 40 times faster than the ordinary telex system; *electronic mail*, somewhat slower than teletex, where words or numbers are communicated electronically, sometimes using *packet switching networks* which transfer data from point-to-point in discrete packets, i.e. more cheaply than if transferred as a continuous stream; *telefax*, which allows facsimile reproduction over long distances by a telephone linked to a computer and VDU at each end; *datel,* whereby information (public or private)[3] is transmitted via a computer/phone system, and *teledata or teletext*, where it is shown on a VDU or television screen; *videotex*, which allows communication by the recipient of the data with its source (used, say, by travel agents to book holidays); and *tele-* or *video-conferencing*, whereby a group of people in different locations can hold a meeting over the phone, with or without visual information. In China (Taiwan), the telecommunications agency offers local subscribers access not only to its information data bank, but also to its computer for *data processing* jobs. Other services which could be developed in the medium term include: remote medical diagnosis; monitoring fire, safety and medical alarms; remote utility meter reading; and telecontrol of mechanical processes and opinion polling.

Banking

3.9 New information technology is being extensively used by banking firms in most developed market economies and a few of the technologically more advanced developing countries (Hong Kong, Singapore) to lower the cost of their services, to improve their quality (especially speed) and to extend their range.[4] In other developing countries the level of office automation, though generally far behind that of developed countries, is more advanced in banking than in other sectors.

3.10 In the front office, banks have invested heavily in automated teller machines (ATMs) and cashier operated terminals. There are over 48,000 ATMs now in the United States compared to 9,800 in 1976, and over 5,000 in the United Kingdom compared to 1,200 in 1979. The substantial investment involved not only in the terminals but also in the network hardware, has restricted their use to the larger banks and building societies, and in Japan this has led to regulations on the hours during which ATMs may be operated, as a means of protecting the smaller banks. Combining unstaffed deposit-taking machines with ATMs has allowed banks to extend their opening hours (including Saturday mornings in the United Kingdom) without any counter-staff. Counter-terminals, which allow transactions to be recorded automatically, can be linked to computers in the back office to provide cohesive branch information. Here, the installation of mainframe computers and, more recently, mini-computers has coped with various data processing tasks, for example settlement of transaction information, target balance reporting, and money transfer facilities, together with systems to allow dealers to update their trading positions quickly, and real time information systems showing market developments. Some banks are also able to offer foreign exchange brokers an automated confirmation service replacing the existing manual method of recording deals between them. At the same time, clearing banks have begun to automate their payments systems, both nationally and internationally. More than 1,500 banks in 39 countries are able to transmit transactions via a computer system operated by the Society for Worldwide International Financial Telecommunications (SWIFT) at a fifth of the cost of telexes.[5] Many banks and credit card companies also operate their own international networks.

3.11 Second generation systems are being developed which could further extend access to bank services, such as home banking (offering information about balances, the ability to transfer funds from one account to another, or even brokerage facilities) and 'cashless shopping' (electronic funds transfer at the point of sale or EFTPOS). Both systems are in operation in a few countries, but as yet on a limited scale, principally because of the high installation costs involved. The benefits (in terms of cutting transaction costs) will depend on the extent to which the systems are used. According to one banker, EFTPOS would not be economic in the United Kingdom even if it replaced all credit card vouchers and half of the cheques used, and plans to launch a nationwide system in 1986 have been temporarily shelved. However a French invention, the 'smart card' (a credit card containing an inbuilt one-chip microprocessor and memory, on which transactions may be recorded) may allow the use of less sophisticated machines (authenticators instead of terminals) in retail outlets, and so lower the cost of cashless shopping. The cards have the added advantage of making

fraud more difficult, while they can also be used for other purposes such as storing individual health records or for identity controls. Meanwhile an EEC study on banking technology concluded that home banking would not be widespread before 1990. Home shopping, which combines elements of home banking and EFTPOS with viewdata information on goods and prices, is another development being promoted in the medium term.

3.12 Besides the hardware embodying these new technologies, there are major costs involved in the development of the associated software, as well as in the reorganisation of the banks themselves. A number of banks have therefore jointly funded R & D companies to develop programmes suited to their various needs.

3.13 While the new information technology is allowing the creation of new financial services and enhancing the quality of existing ones, and is therefore likely to generate increased demand on the banking sector, there is concern among bank workers that the elimination of several manual operations by automation will inevitably reduce the demand for their labour. According to the Clearing Bank Union in the United Kingdom, for instance, employment in the clearing banks will fall by 10 per cent in the next decade. At the same time the occupational skills required will shift from cash handling and administration to financial advising. In India, the opposition of bank workers' unions to computerisation, on grounds of likely job losses, has been a major factor in the banks' failure to instal their own internal telecommunications system.

Insurance[6]

3.14 The earliest and now the most widespread use of electronic data processing technology in the insurance industry was in the automation of accounting, in particular maintaining the customer's policy record. This involves producing premium bills, updating policy accounts, paying agents' commissions, calculating reserve requirements, paying policyholder dividends, and keeping policy loan accounts—as well as computing actuarial tables and managing investment portfolios. Branch office personnel can have rapid access to policy information via real time computer networks for use in preparing specialised insurance packages for individual clients. Thus new technology has allowed the introduction of new products and better customer services, in addition to lowering the cost of accounting, increasing the speed of cash collection, and improving investment management. For example, in the United Kingdom one computer company has announced that it will be providing a national network linking Lloyds syndicates with 'high street' insurance brokers, allowing information on rates to pass quickly

between companies and brokers, and quotations to be calculated with the aid of a software package, as well as handling correspondence between brokers and underwriters. It seems likely that this network will be extended internationally, thereby strengthening Lloyds role in the world insurance market.

3.15 The first category of insurers to become automated has tended to be the life offices, though even here a large proportion of smaller firms have been slow to adopt automated techniques, partly because of the indivisibilities involved. But the advent of the mini-computer and computer service bureaux has made automation economically viable for most small firms. However, there are still problems facing the small independent agencies, affiliated to more than one insurance company. In particular the incompatability of different information systems has meant that each agency has to have a different terminal for each insurance company using a different system. Whether or not standardisation is achieved will depend on the extent to which the industry is prepared to coordinate its technological development.

Tourism

3.16 The rapid changes in the speed and nature of world telecommunications services, notably the introduction of teletex, telefax, national and international data networks, coupled with developments in computer technology, have radically altered the administration of the world tourist industry. There have been three major innovations. First, the use of information networks provides travel agents with almost instant access to details of schedules, prices and availability of flights, hotel rooms and rented cars. There are about 30 such international networks—14 for hotels alone—which are accessible to agents throughout the world via a central switching link in Boston, USA, and many more national ones. Second, most document preparation is now automated, and therefore quicker and more accurate, being produced by micro-computers with a printing capability, i.e. the terminals are attached to the data bases. Third, the same terminals can be used to calculate an agent's total daily sales and also to record marketing information, such as details of customers' requests for new services, which are then communicated to the travel company's headquarters (or the national tourist board) for analysis. In this respect the terminals are used in a way similar to point of sale terminals in merchandise retail outlets.

3.17 These changes have important implications for the development of tourism in developing countries. On the one hand they could help to stimulate demand by improving links with distant and previously unused locations. In addition the ability to confirm flight and hotel

bookings rapidly, if not instantly, by reducing uncertainty (including worries about double-booking) may increase the number of people willing to holiday (or conduct business) abroad. On the other hand, 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 could also apply to hotels (or tour operators) within particular countries—small, locally owned hotels (or tour operators) may find that the cost of participating in such a data network is too high (or that they are unable to obtain sufficient foreign exchange for it). This is likely to reinforce the dominance of hotels owned (or tours run) by TNCs in a tourist industry 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.[7] In response these firms might wish to consider setting up a computer-based marketing network on a cooperative basis. Such a facility already exists in the United Kingdom where several family operated hotels have jointly used the services of a computer bureau to establish a data base, with details of room availability, that can be linked with hotel data networks serving travel agents nationwide. But they will also need to cooperate in other areas (such as the purchase of supplies, legal and financial services) if they are to compete effectively with the larger, transnational chains.

Office automation

3.18 New technology is being used in nearly all the offices of major companies in developed countries and increasingly in smaller companies' offices to improve their capacity to handle words and numbers, and to improve their communications. In most cases the chief objective appears to be to cut costs by reducing the number of staff, but additional aims are to increase the speed and accuracy of office work, and to enhance its usefulness by making it more information-intensive.

3.19 There is a long list of machine categories available for office automation, and a wide range of models within each category, with substantial price differentials. Communication systems having already been discussed, the following concentrates on electronic typewriters, wordprocessors and small (micro, mini) computers.

3.20 Electronic typewriters contain chips which store information on tabs and spacing, and commands. The memory can be used to store text until all mistakes have been corrected or alterations made, before the text is printed; it can also be used to reproduce standard letters or other documents, and store regularly used names and addresses, or standard paragraphs. The typewriters may be used for printing when

attached to a computer, for example a mobile computer receiving messages across telephone lines, and when two electronic typewriters are linked in this way they can form a type of super-telex system. However, their overall use is still fairly limited, with only 1.8 million being operated in Europe compared to 10 million typists.

3.21 Dedicated wordprocessors allow a greater degree of text manipulation, with a full size screen compared to the single line display of most electronic typewriters, which makes it easier to reposition sentences or paragraphs. They have several other editing facilities such as inserting new paragraphs, as well as storage benefits with large volumes of text being stored on compact floppy or hard disks. Print speeds are almost three times as fast as for electronic typewriters (but still not fast enough to replace photocopiers).

3.22 General purpose micro- or mini-computers with a wordprocessing function are gradually taking the market away from most dedicated wordprocessors. They are generally easier to use and with the large number of software programmes on the market, they can perform nearly all the same handling tasks; moreover they also offer the capacity for data manipulation (for instance financial planning) at little, if any, extra cost.

3.23 One problem with the wide variety of equipment on the market is the risk of incompatibility. Although there have been some attempts to develop 'translators' which allow machinery of different makes to interact, it seems that incompatability is still widespread, even within individual offices. A study of micro-computer use in the public sector in Mexico found more than 350 different models, many mutually incompatible.[8] This invariably increases the need for training and maintenance, and also means that the technological capacity of a piece of equipment may not be fully realised. Another study estimated that as much as 20 per cent of the £5 billion or so spent on information technology in the United Kingdom in 1984 was probably wasted because wrong systems had been chosen and unnecessary capacity installed, with the proportion as high as 50 per cent for smaller companies.[9] A contributing factor appears to be the way in which most decisions on new technology are taken by finance directors rather than by directors of operations. There is also a tendency to overconcentrate on the potential for saving jobs (usually by cutting them) through raising labour productivity, which leads to the neglect of how the new technology can be used in other ways (such as to improve the quality of services).

3.24 According to one estimate the world market for office automation products is growing at more than 15 per cent annually, having reached

$5 billion in 1982; others put the market for word processors in the United States alone at $2 billion in 1980.[10] Certainly the level of investment per office-worker is rising rapidly—in the United States it is forecast to reach $8,000 to $10,000 by 1989, four times that of 1984.

3.25 Despite the gradual reduction in the cost of office equipment, particularly at the lower end of the market, there is little evidence of office automation in most developing countries (with a few exceptions as noted above in the sections on telecommunications and banking). This is partly because the equipment is still too expensive (and the foreign exchange often not available for its import). In addition the relatively low levels of wages have not led to the same pressures for reducing staff sizes. Computers would appear to be an exception, with a significant increase in the use of mini-computers in developing countries in the 1970s. However, computers are still overwhelmingly used for routine data processing applications, rather than linking up with other office (or production) equipment. This makes economic sense given the low wage levels and lack of skills. But in the medium term increasing competition from developed country producers of more automated services may put pressure on developing countries to automate a wider range of office tasks.

NOTES*

1. See UNIDO, *Industry in a Changing World*, New York: UN, 1983, p. 94.
2. The introduction of biotechnology and renewable energy technologies, while clearly affecting the overall cost of health care and transport respectively, may not affect the value added in these services as much as in the pharmaceuticals and energy industries, respectively, and are not therefore considered here.
3. In 1981 there were 472 business and industrial information data bases publicly available, and 223 for science and technology. Most were located in the developed countries. (UNCTAD, *Technology in the context of services and the development process*, Geneva: TD/B/1012, 1984, p. 3.)
4. In the United Kingdom five clearing banks trebled their investment to £750 million in the six years to 1981—an annual growth rate of 19.5 per cent. (R. Barras, *The Case of Office-based Systems,* Paris: OECD, ICCP Series, 1984.)
5. The system itself cost over $1 billion to develop.

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

6. This section draws on S. Globerman, *The Adoption of Computer Technology by Insurance Companies,* Ottawa: Economic Council of Canada, 1984.
7. See UNCTC, *Transnational Corporations in International Tourism*, New York: UN, 1982.
8. Nochtieff and Lahera (1982).
9. T. Bevington and M. Hand, *The Barriers and Opportunities from Information Technology—a Management Perspective,* London: A. T. Kearney, 1984.
10. Hoffman (forthcoming).

Appendix 4

Biotechnology

I. DEVELOPMENT OF TRADITIONAL AND NEW BIOTECHNOLOGY

4.1 Biotechnology is a term capable of various interpretations, and covering a wide variety of techniques. But broadly it can be said to involve the use of the principles of microbiology, biochemistry, genetics and biochemical engineering to process materials by employing catalysts, such as enzymes, and micro-orgnisms, and animal and plant cells. By such means it is possible to produce and process food and beverages, produce pharmaceuticals and biochemicals, recover minerals and metals, purify water, and manage industrial and domestic wastes.[1] A crude but useful differentiation can be made between 'traditional' biotechnology and 'new' or 'high-tech' biotechnology.

4.2 'Traditional' biotechnology stretches back thousands of years. It includes the use of organisms in fermentation for making alcoholic drinks or foodstuffs such as cheese; developments in animal and plant breeding, such as artificial insemination of cattle and artificial propagation of fish; developments in the production of serum and vaccines; pasteurisation and sterilisation of foods; innoculation of seeds with rhizobium cultures to enhance legume yields; biological control of crop pests; and developments in antibiotics. Its fruits can be seen in the 'green revolution' which has occurred in parts of the Third World, particularly in Asia.

4.3 'New' biotechnology is usually restricted to practical applications of some of the most recent advances in chemistry, biology and genetics. It includes genetic and cellular manipulation; 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); and enzyme production and reaction. But new biotechnology

is more than the latest phase in a historical continuum. It is evolving so rapidly that discoveries often overwhelm even recent advances. It also has implications for a far wider range of economic and social activities than did past biotechnology innovation. For all countries, but especially developing countries, it provides new opportunities to alleviate food shortages, treat human and animal diseases, generate renewable sources of energy, and generally achieve higher rates of economic growth and improve the quality of life.

4.4 Modern biotechnology may be said to have originated from experiments in industrial and pharmaceutical fermentation extending from 1910 to 1940. These led to the large-scale production of basic chemicals (for example acetone, butanol and ethanol) and, during the Second World War, to penicillin. They were followed by other antibiotics, and later by the production of what had been rare substances such as steroids, enzymes and certain vitamins.[2]

4.5 Knowledge of genetics has expanded similarly. Efforts to improve the genetic characteristics of plants and animals, through screening and crossing different varieties, have become increasingly refined since Mendel's seminal work, but advances in scientific research over the past thirty years have revolutionised genetics. Since the discovery of the chemical structure of deoxyribonucleic acid (DNA)[3] in 1953, scientists have advanced their understanding of the molecule and have defined its relation to protein synthesis. In the 1970s further research into molecular biology resulted in the recognition that the living cell is a collection of hundreds of thousands of controlled chemical reactions. It also led to the development of major techniques in genetic engineering relating to recombinant DNA (rDNA) and cell-fusion technology. rDNA technology advanced significantly in 1973 when a DNA sequence (containing several genes) was transferred from a donor organism to a host organism where it was chemically spliced, or recombined, in the host's genetic structure. Such techniques enable scientists to engineer genes or introduce them from one organism to another in order to give the recipient its desired characteristics. In this way, it is possible to insert the genes for producing human growth hormones, insulin, or antiviral interferon into fast-growing bacteria for biological production.

4.6 Similar advances followed in cell fusion after 1975 when a cell which produced an antibody (but would not reproduce in tissue culture) was fused with another which grew well in the laboratory. The resultant hybrid cell (hybridoma) was able to multiply and give rise to identical cells (clones) which produced the required antibody (the monoclonal antibody or MCA). MCAs can be used to detect minute quantities of almost any substance, but so far their main use has been to detect antibodies which indicate the presence of disease, thereby enabling

doctors to diagnose diseases much earlier than previously. In future, MCAs are likely 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.[4] Cell fusion is currently used in most plant bioengineering because of the lack of knowledge of the molecular base for gene expression in plants, but in the longer term gene transference is expected to become more important.

4.7 Developments in genetic engineering, particularly protein engineering (where genes are artificially cultured before insertion in the host), are leading to improvements in the production of enzymes for a wide range of uses as catalysts in industry or in pharmaceutical production. This has been made possible by the ability of the enzyme-producing bacteria to reorganise themselves in many ways and reproduce on a large scale through fermentation techniques.

4.8 Table 4.1 overleaf summarises some of the more important developments in the commercialisation of new biotechnology over the past decade. It should, however, be stressed that full-scale commercial application of many of the latest innovations is a long way off, and the continued importance of advances in traditional biotechnology should not be underestimated.

II. BIOTECHNOLOGY APPLICATIONS

4.9 The areas of application of biotechnology are wide: not only can new and improved species and hybrids of plants and animals be developed, but substances which are valuable, rare, or do not occur in nature, can be synthesized on a large scale. Moreover, some of the products of genetic engineering (for example enzymes and bacteria with special properties) can, in turn, lead to more efficient techniques in processing food, pharmaceuticals, chemicals, etc. These may require less energy, fewer production stages or lower priority in material inputs. Tables 4.2 to 4.4 (pages 53–56) summarise existing and potential applications, worldwide.

4.10 From the viewpoint of developing countries, biotechnology may make one of its most vital contributions in food and agriculture. According to the FAO, 55 developing countries, with more than a billion people, are no longer able to feed themselves at acceptable levels of nutrition: in Africa alone some 225 million people are undernourished and a score of countries are facing acute food shortages;

Table 4.1

Major Recent Events in the Commercialisation of Biotechnology

1973 First gene cloned.

1974 First expression of a gene cloned from a different species in bacteria. Recombinant DNA (rDNA) experiments first discussed in a public forum (Gordon Conference).

1975 US guidelines for rDNA research outlined (Asilomar Conference). First hybridoma created.

1976 First firm to exploit rDNA technology founded in the United States (Genentech).
Genetic Manipulation Advisory Group started in the United Kingdom.

1980 Diamond vs. Chakrabarty: US Supreme Court rules that micro-organisms can be patented under existing law. Cohen/Boyer patent issued on the technique for constructing rDNA.

United Kingdom sets targets for biotechnology (Spinks' report). Federal Republic of Germany does likewise (Leistungsplan). Initial public offering by Genentech sets Wall Street record for fastest price increase per share ($35 to $89 in 20 minutes).

1981 First monoclonal antibody diagnostic kits approved for use in the United States.
First automated gene synthesizer marketed.
Japan and France set targets for biotechnology.
Industrial Biotechnology Association founded.
Over 80 new biotechnology firms established by end of year.

1982 First rDNA animal vaccine (for colibacillosis) approved for use in Europe.
First rDNA pharmaceutical product (human insulin) approved for use in the United States and the United Kingdom.

1983 First plant gene expressed in a plant of a different species. $600 million raised in US public markets by new biotechnology firms.

Source: US Congress (1984).

Table 4.2

Implementation of Genetic Engineering Procedures: Some Market Predictions

Product category	*Number of compounds*	*Current market value ($ million)*	*Selected compound or use*	*Time needed to implement genetic production (years)*
Amino acids	9	1,703	Glutamate	5
			Tryptophan	5
Vitamins	6	667.7	Vitamin C	10
			Vitamin E	15
Enzymes	11	217.7	Pepsin	5
Steroid hormones	6	367.8	Cortisone	10
Peptide hormones	9	268.7	Human growth hormone	5
			Insulin	5
Viral antigens	9	n.a.	Foot-and-mouth disease virus	5
			Influenza viruses	10
Short peptides	2	4.4	Aspartame	5
Miscellaneous proteins	2	300	Interferon	5
Antibiotics	4*	4,240	Penicillins	10
			Erythromycins	10
Pesticides	2*	100	Microbial	5
			Aromatics	10
Methane	1	12,732	Methane	10
Aliphatics (other than methane)	24	2,737.5	Ethanol	5
			Ethylene glycol	5
			Propylene glycol	10
			Isobutylene	10
Aromatics	10	1,250.9	Aspirin	5
			Phenol	10
Inorganics	2	2,681	Hydrogen	15
			Ammonia	15
Mineral leaching	5	n.a.	Uranium	
			Cobalt	
			Iron	
Biodegradation	n.a.	n.a.	Removal of organic phosphates	

n.a. Not available.

* Figure indicates classes of compounds rather than number of compounds.

Source: Bull et al (1982).

Table 4.3

Biotechnology Uses and Products and Some Market Forecasts

Sector		*Products*	*Estimated Market ($mn)*	*Time-scale*
Chemicals:	organic (bulk)	Ethanol, acetone, butanol, organic acids (citric, itaconic), amino acids	Bulk chemicals/synfuels; 3,600 by 1990 (amino acids only)	Outlook depends on long-term oil price prospects. Could become attractive by end of century
	organic (fine)	Enzymes	Uncertain: dependent on economics of alternative non-biotech methods of enzyme production	Long-term view necessary
		Perfumeries	Uncertain	
		Polymers (including polysaccharides)	Plastics, uncertain	Unlikely to become viable before end of century
	inorganic	Metal beneficiation, bioaccumulation and leaching (Cu, U)	Minerals and oil together estimated at 4,500 by end of century	Interesting but speculative area, dependent on economics of mineral and oil extraction
Pharmaceuticals		Antibiotics, enzyme inhibitors, steroids, vaccines	Drugs; 8,000 by early 1990s, increasing thereafter according to new developments	Only few products on market to date. Upfront costs and regulatory delays make this a long-term if vast field
		Diagnostic agents (enzymes, antibodies)	2,000 including non-radioactive kits and monoclonal RIA kits	Already on market. Could reach full potential by 1990. Best short-term return
Energy		Ethanol (gasohol), methane (biogas), biomass	Uncertain	Outlook depends on long-term oil price. Could become attractive by end of century

Food	Dairy, fish and meat products; beverages (alcohol, tea and coffee); bakers' yeast; food additives (antioxidants, colours, flavours, stabilisers); novel foods; mushroom production; starch products; glucose and high fructose syrups; functional modifications of protein; pectins; toxin removal; amino acids; vitamins	Food and drink; impossible to quantify	Human food likely to encounter consumer resistance. Fair medium-term potential for animal feedstuffs
Agriculture	Animal feedstuffs; ensilage and composting processes; microbial pesticides; rhizobium and other N-fixing bacterial innoculants; mycorrhizal innoculants; plant cell and tissue culture (vegetative propagation, embryo production, genetic improvement)	Impossible to quantify	Attractive medium-term area with worldwide potential once scientific problems overcome
	Veterinary vaccines and products	2,000 by 1990	Good short-term potential due to less stringent regulations. Market growth depends on farming economies
Service industries	Water purification; effluent treatment; waste management	Biotech applications could reach 2,000 by 1990. Increased environmental concern would help	Already in use in some areas. Medium/long-term view
	Analytical tools	Biotech equipment and supplies currently estimated at 200 per year; growth very rapid	Good short-term 'back door' method of gaining profits from biotechnology
	Oil recovery	(See inorganic chemicals above)	

Source: Bull et al (1982) and Elkington (1983).

Table 4.4

Value of Applied Genetics and New Biotechnologies in Various Market Segments in the United States

Market segment	*1982 ($mn)*	*1985e ($mn)*	*1990f ($mn)*	*Average annual increase, 1981–90 (%)*
Diagnostics	6.0	45.0	2,525.0	95.6
Vaccines/antigens	0.0	25.0	1,000.0	259
Pharmaceuticals	20.0	380.0	7,180.0	92
Chemicals	1.0	10.0	270.0	86
Plant agriculture	0.1	0.5	2.5	43
Animal agriculture	8.0	59.0	433.0	5.8
Processed foods (incl. alcoholic drinks, sweeteners, bread, dairy, etc.)	22.5	199.5	1,847.5	63
Misc. applications (mining, waste treatment, etc.)	1.5	13.5	120.0	63
Total	59.1	732.5	13,378.0	82.6

e Estimates. *f* Forecast.
Source: Elkington (1983).

some are experiencing famine. Moreover, the population of developing countries is expected to increase some two-and-a-half times by the year 2025, with a tripling in Africa where resources are currently under greatest stress.

4.11 Traditional biotechnology plays an important role in food production in the developing countries—in conventional plant breeding and animal husbandry and in food processing using conventional fermentation processes (for example bread, beer, cheese). However, new fermentation products, such as polysaccharides (bio-engineered sugar substitutes) and mycro-protein (based on a micro-fungus which can upgrade most carbohydrates to protein), are unlikely to have early application in developing countries, although their production in the developed countries could adversely affect developing countries' exports.

4.12 On the other hand, genetic engineering and certain other new biotechnology processes are already beginning to be used, albeit to a limited extent, in agricultural practices in developing countries. Their potential impact on agricultural output in the longer term is vast. As indicated above, rDNA can change the genetic characteristics of plants to increase their productivity or enhance their nutritional or other values. And cell manipulation can vastly increase the number of uniform plants available, or widen the range of genetic material from which desirable genes may be extracted to enhance the hereditary characteristics of plants. A few examples of many recent developments include

a high-protein rice which has been developed in China by introducing soya proteins into rice plants; the high-yielding CICA 8 rice developed in Latin America, which is more nitrogen efficient, requires less weeding and can be grown with reduced irrigation requirements; and a high-protein 'sunbean' developed in the United States by introducing the genes of sunflowers into french beans. In Malaysia, cell and tissue culture techniques have been used to clone oil palms and vastly increase yields of oil and kernels in a project estimated to have cost Unilever some £1.5 million and Malaysia about $M10 million. Field trials of clonal oil palms are now taking place in a number of other developing countries (Brazil, Cameroon, Colombia, Indonesia, Papua New Guinea and Zaire)[5].

4.13 Geneticists and biologists are striving to engineer other desirable characteristics in plants to increase yields. For example, by making plants more hardy to extend their growing season or geographical range; by reducing their growth cycle to permit more harvests per year; by increasing their density; by strengthening their resistance to disease and adverse weather; and by increasing the size of the product and the ratio of edible matter to waste.[6] In addition, since the two major increases in petroleum prices during the 1970s, there has been an increased need to develop nitrogen-fixing organisms to raise soil fertility and lessen the need for chemical fertilizers. Genetic engineering may assist in this respect by making it possible to develop more crops which, like certain legumes, can fix atmospheric nitrogen.

4.14 There are also applications of biotechnology for producing animal feed which differ from that for human food, in that the degree of conversion in the basic materials need not be so great, and safety and preservation legislation tend to be less stringent. The production of a single-cell protein as a feed additive has already been tried in Britain, but there are also several low-technology processes of significance to developing countries, for example solid-state fermentation of straw (composting) under non-sterile conditions using selected fungi to produce an enhanced protein feed equivalent to hay.

4.15 Genetic engineering is likely to make a considerable contribution to animal husbandry. It can do so through the development of animal vaccines and antibiotics to control disease; through the supply of growth promoters or hormones; and through the improvement of genetic composition in order to enhance size, vigour, resistance to disease and efficiency in converting animal feed to animal protein, and to control the sex of offspring.

4.16 Biotechnology for therapeutic uses in medical and veterinary care is likely to become increasingly important for developing countries over

the medium term. Genetic engineering offers the opportunity for large-scale and economic manufacture of many drugs and vaccines, which because of their modest cost could be widely distributed among these countries and improve their inhabitants' general health. As already mentioned, rDNA techniques are already beginning to produce much needed proteins, such as human growth hormones, insulin and interferon, and they are expected to lead to the production of vaccines against other viral diseases in humans and animals (including herpes, influenza and certain tropical diseases). MCAs are being used to enhance the ability of doctors and veterinarians to diagnose disease and monitor biological functions (such as reproduction) more readily. In the longer term, it is hoped to treat genetic diseases by the manufacture of proteins (which because of defective chromosomes cannot be produced in the patients' cells) in recombinant clones which can be administered to patients, or by the insertion of functioning genes into the patients' genetic material to restore functions.

4.17 Another major area of application of biotechnology is in the production of alternative sources of energy. This is dealt with more fully in Appendix 6; here it is enough to point out that traditional and new biotechnology can assist in a number of energy-related areas of particular interest to developing countries. For example, biotechnology can contribute to the large-scale production of ethanol (from sugars and starches) or methane and methanol (from wood or ligno-cellulosic material) to provide alternative fuels or chemical feedstocks. It can also contribute to increasing supplies of biomass (for example through cloning plants from prolific and fast-growing varieties of tree species) and improving its conversion into energy, a vital matter in view of the large proportion of the populations of developing countries who continue to rely on biomass for domestic 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 the energy available to developing countries.

4.18 In the longer term, biotechnology is likely to make a positive impact on pollution control and waste recycling in general. Sewage and other municipal wastes already pose serious pollution and health problems in many developing countries, and the issue of recycling will increase in significance with the growing need to conserve natural resources and to tackle industrial pollution. There are a variety of approaches to the utilisation of wastes, and the range of potential substrates is wide: from agriculture (straw, bagasse, maize cobs, bean and nut hulls, oil-seed pressing wastes, bran, fruit skins and pulp, and animal manure); from forestry (wood wastes, liquor, bark, sawdust, paper and fibre waste); and from industry (sugar, meat and other food

wastes from processing and canning, and distillery wastes). It is expected that microbial techniques will eventually assist in both water purification and waste reprocessing, where processed waste can be used as building materials, fertilizers or animal feedstuffs, as well as for the fuels and chemicals mentioned in the previous paragraph.

III. BIOTECHNOLOGY RESEARCH AND DEVELOPMENT

4.19 Government support for biotechnology R & D has been vital in the initial stages of this high-risk activity. In the developed countries it has taken the form of full or partial funding of the scientific research programmes of universities and specialised institutions such as agricultural research centres, as well as of industrial enterprises, for whom governments have on occasions also made available resources for the commercialisation of R & D results. Table 4.5 shows the public funding of biotechnology R & D in 1982.

Table 4.5

Public Funds for Biotechnology R & D, 1982

	Biotechnology R & D £mn	*Biotechnology-relevant R & D £mn*
Germany (FR)	21	75
France	18	48
United Kingdom	26	34
Italy	7	20
Netherlands	6	15
Belgium	5	8
United States	135	360
Japan	35	n.a.

Source: New Scientist, 9 February 1984.

4.20 Few developing countries are in a position to provide government funds for R & D in biotechnology although the more technologically advanced among them do so. For example, in India some Rs 250 million (around $25 million) is expected to be spent each year on biotechnology R & D, out of a total annual research budget of Rs 7,500 million ($750 million), during the current five year plan.[7]

4.21 In the developed countries, private enterprises and numerous foundations are also financing programmes for biotechnology

innovation and commercialisation, and at a scale many times that provided by public sector support. The firms involved comprise both small-scale enterprises engaged in R & D and consultancy (examples include Genentech and Biogen in the USA and Celltech in the UK), which are largely financed by venture capital; and large-scale transnational corporations (TNCs) primarily engaged in pharmaceuticals, petroleum, food and beverages, which have developed strong links with university researchers and small-scale firms, as well as having their own biotechnology R & D, manufacturing and marketing units. The industry has been particularly dynamic in the United States, where over 100 biotechnology companies were established between 1976 and 1983 and R & D expenditure has been almost twice that of Western Europe and Japan combined.[8]

4.22 In the United States, pharmaceuticals biotechnology R & D can be said to play a role broadly analogous to that of the military in the development of microelectronics. The sectoral distribution of US biotechnology R & D has been estimated as follows (percentages): pharmaceuticals 62; speciality chemicals and food 20; commodity chemicals and energy 15; environment 11; and electronics 0.3[9]. Comparable data are not available for other countries, but pharmaceuticals appear to have been dominant in many of them, and the number of companies in the healthcare sector has risen markedly (see Table 4.6). Some countries, however, have specialised in different areas, for example Japan in fermentation technology and the United Kingdom in plant science.

Table 4.6

Biotechnology Organisations in Healthcare*

Region	*Academic institutions*	*Corporations*	*Specialist companies*	*Total*
Europe & Israel	162	106	32	300
USA, Canada & Mexico	137	111	146	394
Japan, other Asia & Australia	51	83	2	136
Total	350	300	180	830

* 1982 data for 27 countries.
Source: Elkington (1983).

IV. BIOTECHNOLOGY AND DEVELOPING COUNTRIES: IMPACTS AND ISSUES

4.23 Although there are few indications as yet on how developments in biotechnology are likely to affect developing countries, there is little doubt that they will be extensive and far-reaching. There will be direct impacts on producers in agriculture and other industries, and indirect ones through international trade; in both cases there will be effects on employment and on the pattern of income distribution.

4.24 The effects on agriculture are likely to be crucial, although it is difficult to draw parallels with the experiences of the green revolution. In the first place, the expensive inputs of fertilizers, pesticides, fungicides and irrigation needed to support the production of high-yielding varieties (HYVs) are unlikely to be required on the same scale. The advantages of the gene revolution are expected to come from developing high-yielding plants which will have in-built resistance to drought, insects, disease, etc. Moreover, the HYVs developed during the green revolution concentrated on wheat and other cereals appropriate to parts of Asia and Latin America but not, in the main, to Africa. Grains such as sorghum and millet, and pulses and rootcrops, so important to Africa, were much less affected. However, the new biotechnology presents opportunities to develop a wider variety of crops. Whether those of interest, say, to subsistence farmers in Africa, will be markedly improved depends to some extent on who undertakes the R & D and hence who controls the technology. While the work of international institutes such as the International Maize and Wheat Improvement Centre (CIMMYT) in Mexico and the International Rice Research Institute (IRRI) in the Philippines, and of regional and national institutes will continue to be important, it is the TNCs who control most of the technological developments taking place at present.

4.25 The question of who controls the new biotechnology may be critical. The green revolution was mainly the product of public sector research, and the resultant products and processes were generally widely diffused. The control by TNCs of the 'gene revolution' has a number of implications for developing countries. Three are especially important—access to technology, the location of production and the development of substitutes—and could result in the displacement of agricultural exports from developing countries, with marked effects on their balance of payments, income and employment.

4.26 Since most of the new products will probably continue to originate from TNCs, the technology gap between developed and developing countries may widen. The problem of access to biotechnology is likely to be exacerbated by two elements: the existence of property rights; and

the increasing cooperation between industry and academic institutions, which is resulting in secrecy to protect commercial interests and an absence of dissemination of R & D results.

4.27 Although publicly-funded international and regional research institutes are seeking to develop crops of importance to developing countries, their resources are comparatively small. According to one estimate[10], the top 50 companies in the United States have invested more than $1 billion in biotechnology R & D. By comparison, the annual research budget of the International Centre on Genetic Engineering and Biotechnology (ICGEB), on which many developing countries are pinning their hopes, is $9 million.

4.28 While developments in new biotechnology will offer many positive opportunities for developing countries, there are negative effects. Biotechnology makes it possible to grow in temperate climates—outdoors as well as in the laboratory—products which hitherto have been grown only in the tropics. For example, it has been estimated that increasing the temperature tolerance of a tomato plant by 1°C could lead to a trebling of outdoor production of tomatoes in Britain. Of even greater significance is the fact that improvements in plant tissue culture could provide viable alternative to plantations for producing rare or specially valuable substances (for example drugs, perfumes, spices) and at the same time enable the development of alternatives to certain existing plantation crops (for example cocoa and sugar-cane: one plant under investigation is reputedly 200 times sweeter than cane-sugar). The impact on developing countries' agricultural exports, income and employment could be significant, since their exports of medicinal plants alone were valued at $500 million in 1983.

4.29 The increasing shift to laboratory-farming, whether in developed or developing countries, will have considerable labour-displacing effects, since tissue culture factories will not depend on agricultural raw materials that are produced under labour-intensive conditions.

4.30 On the other hand, the potential for increases in multiple cropping is likely to lead to greater demand for labour in developing countries; it will also cause changes in demand for particular types of land, in ownership patterns and in income distribution. Although the last is largely a product of existing patterns of economic and social organisation (notably systems of land tenure, access to credit and marketing outlets), it is probable that the effects on agricultural employment of what might be called the second green revolution will be similar to that of the first, where, despite considerable local variations, there was evidence that larger land-owners benefited at the expense both of

smaller ones and of tenant farmers, with an increase in the employment of hired labour and a decrease in that of family labour.

4.31 Whether the application of new biotechnology will have any significant effect on farm-size is difficult to judge. Although the technology itself is not scale-biased, its indirect effects may well have an impact on farm-size through such factors as ease of access to new biotechnology products and processes and initial price of the technology. According to the US Office of Technology Assesssment, new technologies (of all kinds) are accelerating the creation of large industrialised farm-production units at the expense of small family-farms in the United States mainly because the innovations are costly and complex to implement.

4.32 Besides these economic effects, some of the social and environmental effects of new biotechnology should be considered. They include the need to evaluate, control and conserve the resources of developing countries. Already commercial requirements are leading to the removal of 10 million hectares of forest a year in tropical Asia, Africa and Latin America. This has serious implications not only for the preservation of the environment and the eco-system, but also for genetic balance. Developing countries are estimated to possess at least 70 per cent of the world's genetic material (germ plasm) needed for selecting useful breeding characteristics through new biotechnology techniques. Adequate steps have not yet been taken to control the exploitation of these resources, and gene banks urgently need to be established to enable these countries to maintain their genetic variability. An International Board for Plant Genetic Resources (IBPGR) has been established in Rome,[11] but it might be useful for countries possessing similar environments, or growing common crops, to cooperate in collecting and evaluating particular germ plasm resources.

4.33 Biotechnology offers considerable potential for collaboration between developed and developing countries, although the latter will have to be vigilant in guarding not only against possible over-exploitation of their genetic resources but also against being used as a testing ground for new biotechnology products of uncertain safety. The OECD Report on Biotechnology[12] emphasized that all countries should have regulations concerned both with health and safety and with protection of the environment. Unification of standards for safe laboratory practice and procedures (an issue being examined by the Scientific Panel of Experts at the ICGEB in New Delhi) should be encouraged internationally.

4.34 Some advances in human genetics have raised ethical questions relating to the manipulation of the human embryo and the insertion of

human genes into other species. These questions have to be reconciled with the religious and cultural views of individual countries. But there are other ethical questions related to commercial practices, such as the possibilities for companies to distort breeding programmes in order to satisfy commercial objectives. For example, since clonally-propagated crops are currently many times more susceptible to disease and pests than are their seed-bred counterparts, agro-chemical companies are in a good position to profit from the confluence of plant protection products and plant-breeding research. Some observers fear that private industry could use its ability to manipulate genes in order to sell more chemicals.[13]

V. CONCLUSION

4.35 Over the next decade or so, it is expected that developing countries will continue to benefit more from traditional than from new biotechnology, especially in the production of food and chemicals through conventional fermentation processes, and in plant breeding and animal husbandry.[14] But in the longer term, the potential applications of new biotechnology are such that it can make a very real contribution to Third World development. For it to do so, however, will require developing countries to understand better its techniques for solving specific problems and to become more aware of available sources for its applications. Both require expertise and other skills.

4.36 At present the major constraint faced in this respect by developing countries is a lack of trained personnel. It has been suggested[15] that these countries should try to establish, on a national or regional basis, core technical groups comprised of some 9 to 14 researchers and technicians specialising in organic chemistry, biochemistry, immunology, microbiology, engineering, and electronics. A lack of up-to-date laboratory facilities and equipment is a related constraint. On the other hand, the direct costs of biotechnology R & D are often not particularly high or constraining.

4.37 An immediate requirement for developing countries in the area of biotechnology is to analyse their national needs and establish priorities according to their own resource endowments. This would allow them to concentrate on those areas where new biotechnology applications could be most productive. In deciding priorities, the determining factors could be, for example, import substitution; optimal use of raw material and other feedstock for biotechnology products; alternative uses of raw materials for which export demand is diminishing; manufacture of biotechnology products which would solve pressing national problems

(such as endemic diseases and pests, malnutrition, pollutants). Such exercises should assess not only the reliability of raw material supplies for biotechnology processes, but also the markets for the resultant products.

4.38 Many of the institutions in developing countries are capable of adapting to those areas of biotechnology (genetic engineering, enzyme engineering and fermentation technology) required to develop applications in particular sectors of agriculture and industry. But most of them have yet to develop a sufficiently close relationship with industry to ensure their R & D is based on real needs. In some cases a more adequate coordinating mechanism may be needed.

4.39 To ensure the effective future utilisation of biotechnology, developing countries will need not only to strengthen their national capability but also to enhance international institutions (ICGEB, IBPGR and other research centres). Finally, but crucially, they will need to increase their bargaining strength vis-a-vis TNCs. A detailed knowledge of the potentials of new biotechnology and an appreciation of their own genetic resources will be essential in this regard.

NOTES*

1. Based on Bull et al. (1982).
2. UNIDO, *The Promise of Biotechnology and Genetic Engineering for Africa;* UNIDO, IS. 513, p. 2.
3. For definition see Glossary (Volume I, Appendix 1). Laboratory techniques now exist for making synthetic DNA molecules, and scientists are able to cut and splice those molecules in order to introduce them into other cells to provide the genetic characteristics desired.
4. UNIDO, op. cit., p. 3.
5. Elkington (1983).
6. Narang (1981).
7. *Commerce* (India), 22 October 1983.
8. Annual expenditure on biotechnology R & D is estimated at around $2 billion in the United States and $1.25 billion in Western Europe and Japan.
9. U.S. Office of Technology Assessment (1984) p. 7. (The fact that the sum of the items exceeds 100 per cent presumably reflects some element of double counting.)

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

10. F. H. Buttel et al., 'From Green Revolution to Biorevolution: Some Observations on the Changing Technological Basis of Economic Transformation in the Third World'; *Cornell Rural Sociology Bulletin*, No. 2, August 1983.
11. Its aim is to promote the collection, documentation, evaluation, conservation and utilisation of genetic resources of important species, especially in those areas where the spread of new varieties may put traditional ones in danger of extinction, and to support training in aspects of genetic resource work.
12. Bull et al., op. cit.
13. Dembo et al. (1985).
14. Borlaug, for example, concluded that 'since it is doubtful that significant production benefits will soon be forthcoming from the use of genetic engineering techniques with higher plants, most research funds in crop improvement should continue to be allocated for conventional plant breeding'. (N. Borlaug, 'Contributions of Conventional Plant Breeding to Food Production'; *Science,* Vol. 219, No. 4585).
15. See *Exchange of Views with Experts on the Implications of Advances in Genetic Engineering for Developing Countries,* UNIDO IS. 259 (1981).

Appendix 5

New Materials Technologies

I. GENERAL TRENDS

5.1 In recent years, a series of technological breakthroughs have been achieved in developing new materials for a wide range of purposes. These advances have taken place in various materials (including metals, ceramics, composites and polymers), either through developing new types of material or by applying new processing technology to existing materials. In particular, there has been a swing away from metals to ceramics and polymers, a trend which has occurred despite the many kinds of coating being developed to improve metal conservation qualities (such as greater resistance to abrasion and corrosion) and thus to extend the 'life' or use of the final product. Among polymers there has been a gradual movement from those based on petroleum feedstock towards alternative feedstocks, and more significantly, towards ceramics based on common elements (such as oxygen, silicon, calcium).

5.2 Although many of the new materials technologies are still at the R & D or demonstration stage, and are not likely to be used to any significant extent for at least a decade, the above trends imply that resources needed for some future major materials will be available to all countries, rich or poor, whether petroleum-endowed or not. It thus seems possible that in the longer term, a mixture of polymer-based and ceramic-based low-temperature composites could be produced in most if not all countries—including developing countries—using relatively low-cost technology appropriate to each country's own conditions, with all the ensuing advantages that this would entail.

5.3 New materials and process technologies cover a diverse and expanding field. They include: base materials, both organic (such as plastics and rubber) and inorganic (for example ceramics, new cements, metals and alloys) which possess improved purity, structure and composition; reinforced composites which mix fibres in conjunction with base

materials to strengthen or enhance them; and new processes, including methods of forming close to final shape, methods of joining parts—such as adhesives—and providing surface treatment to metals and materials to improve their durability. A number of these techniques are still in the early stages of development and are unlikely to be widely used for several decades. However, some of the more mature technologies are likely to be important in the shorter term, either for their potential in creating materials for completely new uses or as potential competitors to existing materials or production processes. Six groups of new materials have received particular attention in this respect, and in the next section we briefly comment on their development and applications.

II. SELECTED DEVELOPMENTS

High-strength low-alloy steels

5.4 One of the most important sectors where new technology is being developed and applied is the iron and steel industry. Here, high-strength low-alloy (HSLA) steels have been developed by using only minor additional alloying agents to enhance the technical qualities of steel in terms of combinations of strength, toughness, formability, ductibility and weldability. These steels are benefiting user industries in several ways, notably in reducing the amount (and therefore the cost) of metal needed to carry a given load. HSLA steels are particularly suited for applications in road vehicle wheels, bodies and structural parts, in other aspects of transport such as building ships, railroad freight cars, bridges and pipelines, as well as in manufacturing heavy equipment, including cranes, and assembling prefabricated buildings.

5.5 The technology for producing HSLA steels is already commercialised, though still being refined. It produces higher value-added products than plain carbon grades of steel and is a more cost-effective process. HSLA steels are consistent with materials conservation, in that less material is needed per unit of final product, and with energy conservation, in that the weight to load ratio is reduced. Their production does however require a deeper application of metallurgical principles and tighter control of production practices than in the case of ordinary carbon steels, and the optimum use of HSLA steels in industrial applications requires designers to be well informed about the particular properties and characteristics of the material. This higher level of skill requirement may be an important constraint on the effective use of HSLA steels in developing countries in the near future but should be overcome in time.

Powder metallurgy

5.6 Powder metallurgy involves the production of metal powders which are compressed, and sprayed or sintered as necessary, to produce steel strips or near final shapes of components and parts. The technology is well established, but is going through a revival because of a combination of technical advances and economic considerations.[1] In general, the powder route towards metal production is taken when it is the only way to process the material (as in making cemented carbide cutting tools); when powders offer lower processing costs (as in making engineering components and parts from expensive alloys by producing near net shapes from powders which are subsequently forged); and when powders offer superior properties in the manufactured parts.

5.7 Most big steel companies are moving towards powder metallurgy to produce steel strips and thus dispense with the ingot phase. The process promises large savings as it needs only one-third of the plant required for the conventional process.[2] Powder metallurgy represents a highly flexible development in process technology and is especially suitable for producing large numbers of identical parts. The rapid solidification technique has led to improvements in the mechanical properties of many alloys based on aluminium, nickel and steel. Though much of the technology is oriented towards the needs of industrial countries, opportunities exist to develop uses suitable for developing countries; for example, producing sheets by rolling metal powders requires less capital investment than by conventional means. A further advantage is that entry into the technology can be undertaken on an incremental basis, starting in a limited way and subsequently expanding processes and products.

Composites

5.8 'Composites' is a generic term describing engineering and structural materials built up of several components having different properties. One example are the new fibres, such as carbon, boron and polyamide, with high tensile strength, high modulus elasticity and low density, which when embedded in a resin matrix provide composite materials with strength-to-weight and modulus-to-weight ratios far above all previously established levels.[3] Such materials include polymer matrix composites (such as reinforced plastics); metal matrix composites (for example those combining fibrous ceramics with metals); and other composites (including fibre-reinforced ceramics or new cements incorporating polymeric additives) which are largely at the R & D stage.

5.9 Not only is the spectrum of materials wide, but so is the range of technologies needed to produce and apply them; from the conventional (such as glass fibre) to the very advanced. Unlike conventional materials,

which are usually fabricated into components from milled materials, composites are normally fabricated directly into the required shape. Thus, working with them requires a high degree of integration of materials design, mechanics, structural design, fabrication and non-destructive testing as an iterative process. Success depends on the combined abilities of the designer, structural analyst, materials specialist and fabrication engineer. Non-destructive testing is specially important, since some flaws can be detected only during processing.[4]

5.10 These requirements could constrain the production and use of many composite materials in developing countries. Nevertheless, the composites' wide range of applications, the compatibility of their production technology with the requirements of small and moderate sized markets, and their widespread substitution possibilities, make some of them particularly suitable for developing countries. In certain cases, their production may require only low-cost, locally-available resources and be labour intensive compared with conventional materials production. One example of this are the fibre-reinforced structural materials, where local fibres (such as sisal or bamboo) can be used; another is glass fibre, which involves an already mature technology. For developing countries in general, a graduated approach to new materials is needed, perhaps using, say, glass fibre-reinforced plastics as an industrial base on which to build expertise in other advanced fibre-reinforced composites over a longer term.

Polymers

5.11 Polymer materials, in addition to their use in polymer matrix and other composites, are now well established in a variety of other uses as substitutes for a range of traditional materials (notably timber and metals). Advances in this field are continuing, particularly in the use of polymer fillers (organic or inorganic) which reduce requirements for petrochemical feedstock, and in process technology which saves energy and lowers costs. Developing countries possess a range of materials which could be used as fillers: examples include slag or quartz sand for inorganic fillers and agricultural waste for organic ones. Current R & D could, in the long term, lead to the large-scale production of plastics from biomass, and thus enable many developing countries to become self-sufficient in this basic industrial material.

Engineering ceramics

5.12 Engineering ceramics are a category of fine ceramics which have been developed at high temperatures, usually from compounds including such elements as silicon, carbon, oxygen, nitrogen, aluminium and zirconium. They are light, stiff, resistant to corrosion and friction and have low thermal and electrical conductivity, properties which are

increasingly attractive in engineering applications. The technology to produce them is costly, however, and still mainly at the R & D stage, although research is widening the number of new materials (such as oxides) which can be used to form ceramics of engineering quality. Their potential applications include use in advanced diesel and gas turbine engines, cutting tools, process plant, medicine and dentistry.

Electronic materials

5.13 The rapid advances in the microelectronics sector owe much to developments in materials processing, and the creation of new materials has enabled microelectronics applications to be extended in several directions. One prominent example is the use of optical fibres in telecommunications and information networking.

5.14 New materials processes have been used in the manufacture of semiconductors, based largely on silicon and gallium arsenide, and research is continuing into superlattices.[5] Further advances in microelectronics depend on the development of materials to improve electronic devices (for example, by increasing the speed of flow of electrons while reducing power dissipation) and electronic components (including materials for improved luminescent displays, new alloys for component interconnection, encapsulation materials).

5.15 Research into new electronic materials is taking place almost entirely in developed countries and, at least in the medium term, the impact on developing countries is likely to be restricted to these countries' use of the resultant materials.

III. GOVERNMENT SUPPORT

5.16 The development of new materials remains a high-risk activity involving long lead-times and depending on government financial support. Most of the R & D is related to the defence, nuclear and engineering sectors.

5.17 Information on government support for new materials R & D is somewhat fragmentary, but a recent report[6] indicated that in the United Kingdom approximately £50 million a year is spent on this activity by government-sponsored R & D institutions. (Total R & D expenditure by UK manufacturers was approximately £3.5 billion in 1981, but it is not known what proportion was on new materials technologies.) In the United States government support for materials R & D is estimated at over £750 million per annum, with basic research funding estimated at 30 per cent and applied research funding at 60 per cent of the total.[7] About £66 million of this was spent on engineering ceramics. In Japan,

MITI's project on basic technologies for future industries is the country's most important programme of this type. Funded at around £300 million per annum over at least eight years, it embraces R & D into new materials, electronic devices and biotechnology. Total Japanese R & D into new materials is probably in excess of £200 million a year.[8]

IV. IMPLICATIONS FOR DEVELOPING COUNTRIES

5.18 Since the term 'new materials' is not a precise one, market size cannot be determined. But these materials are likely to have significant economic effects over the longer term. One major impact is likely to be on the markets for traditional materials; the development of new materials may have a considerable impact on demand for commodities and thus on developing countries' exports. This effect could be specially marked for those countries whose export earnings are dependent on a few commodities (such as copper, bauxite, tin, timber, cotton, jute) which could eventually become obsolete through the development of new materials. There is an implication here for those commodity producers to institute advanced R & D programmes to find new uses for such commodities. The key to a niche in the market place must be continuing R & D. It is conceivable that new materials technology could lead to the development of complementary uses for traditional materials, and thus enhance the demand for commodities. Over the longer term, countries that have acquired the technology for producing new materials might be able economically to use these materials to substitute for imports or embark upon exports, with favourable repercussions on their economies. Doubtless all three effects will occur, but at this stage it is impossible to judge which will be the more important.

NOTES*

1. Epremian (1982), p. 13.
2. UNIDO (1982) ID/WG. 341/1, para. 9.
3. Epremian (1982), p. 7.
4. Ibid.
5. Interleaved thin layers of semiconductor materials or of impurities introduced into a semiconductor to tailor specific electrical properties.
6. UK Government, Department of Trade and Industry (1985).
7. Ibid., Annex 3.
8. Ibid.

* Complete references to the works cited are given in Appendix 10, Selected Bibliography.

Appendix 6

Renewable Energy Technologies

I. THE SETTING

6.1 Energy derived from renewable sources such as wood, wind and water has assisted human activity and development for thousands of years. But following the invention of the steam engine and subsequently the internal combustion engine, fossil fuels (coal, petroleum and natural gas) have been increasingly used to meet the energy needs of the modern world. By 1980 they provided about three-quarters of the world's energy (commercial and non-commercial), with petroleum by far the most important of the three. However, steep rises in petroleum prices during 1973–74 and 1979–80 brought about a growing awareness that for reasons both of strategy (dependence) and of geology (depletion of resources), the world cannot continue to rely on this single source for the bulk of its growing energy requirements.

6.2 The transition from low to high cost energy during the past decade changed the pattern of energy usage. The developing countries, most of which possessed relatively unsophisticated energy technology and relied chiefly on imported fossil fuels for their commercial energy, generally missed the cheap and abundant petroleum that helped to fuel the rapid economic growth of the industrial countries. Further industrialisation and other aspects of economic development in the Third World are almost certain to be associated with a continuing marked increase in demand for commercial energy, and because of price (especially of petroleum) and ecological problems (associated notably with biomass and large-scale hydropower), the more efficient use and production of fossil fuels as well as the development of alternative energy sources will be of crucial importance. Each will depend on the development and application of new technologies.

6.3 New energy technologies cover a wide spectrum. They include improved techniques to convert primary energy into secondary energy

(for example thermal electricity—where in some processes over half the primary energy is lost as waste heat); they also include techniques to increase end-use efficiency through new processes and products (for example heat pumps and fluidized-bed combustion), and in other ways to conserve energy (such as through a better organisation of the thermodynamic balance in industries). Their impact is thus felt not only directly within the energy sector itself—in the production, transportation and conversion of energy—but also indirectly, in the way in which energy can be used to produce goods and services or consumed as a final product. Here we concentrate on the new technologies associated with renewable sources of energy, especially those of particular interest to developing countries, although in the medium term technologies to improve the efficiency of production, conversion and use of fossil fuels may continue to be more important.

6.4 Renewable energy sources fall into six broad categories: bioenergy—in its traditional solid form as biomass (fuelwood; charcoal; animal, human and vegetable wastes and residues), or converted into liquids (ethanol and methanol) or gas (biogas/methane and producer gas); hydropower, including mini-hydro; solar power; wind power; geothermal energy; and ocean energy (tides, thermal gradient and waves). Nuclear energy is not considered, as although it is new, and in certain instances potentially renewable ('breeder reactors' and nuclear fusion), its capital requirements and potential environmental hazards do not make it *prima facie* attractive to most developing countries at present or in the near future. In the more distant future, however, it may become economic for the larger developing countries such as India, Brazil, Pakistan and Nigeria, some of which already generate electricity from nuclear fuel.

6.5 Renewable sources of energy are estimated to account for 20 to 25 per cent of all energy consumed in developing countries. In the poorer countries, they supply half to three-quarters of the total, and in individual cases the proportions can be even higher—between 70 and 90 per cent in some African countries. Traditional forms of bioenergy are particularly important in the rural areas and among the urban poor, even in middle-income developing countries. By comparison, renewable sources of energy (other than large-scale hydropower) are estimated to contribute only 15 per cent of world energy consumption and a mere one or two per cent of that in the developed countries. Biomass accounts for as much as 90 per cent of the renewable total (though less if human and animal draught power are included).

II. DEVELOPMENT AND APPLICATIONS

6.6 While some renewable energy technologies are commercialised, others are still at the research and development (R & D) stage. Relatively few are completely mature—large-scale hydropower is one exception—as even 'traditional' technologies can be upgraded. Some of the commercialised technologies are undergoing rapid development, with increasing technical effectiveness and declining costs. They include biomass thermo-conversion and bio-conversion technologies, wind turbines, and solar photovoltaic cells and arrays. Other technologies (including those to take advantage of ocean thermal gradients) still await full economic assessment although their technical viability has been demonstrated; yet others (including the photo-biological production of hydrogen) are not expected to become economic over the next 20–30 years.[1]

6.7 R & D on upgrading traditional sources of energy is taking place in both developing and developed countries; in the latter, private sector R & D is often supported by generous government incentives. R & D on the newest forms of energy is being undertaken largely by developed country enterprises, including those in the public sector (such as electricity utilities). But since many of the new products and processes are suitable for developing countries, location-specific factors favour some development in these countries themselves.

6.8 Comprehensive data of R & D expenditure on renewable energy technology by developed country enterprises are not available; but according to the United Nations,[2] bilateral assistance to developing countries for programmes and projects in this field amounted to some $1.15 billion during 1981–83, while international organisations provided a further $232 million. Large-scale hydropower accounted for $1.16 billion (five-sixths) of this assistance, while other sources of energy received relatively modest amounts, viz. geothermal, $68.6 million; fuelwood, $52.8 million; biomass, $13.1 million; mini-hydro, $4.1 million; and wind, $2.4 million; assistance to ocean energy and solar energy was negligible.

6.9 The technological development and applications of these six sources of renewable energy are summarised below, followed by a brief comment on integrated energy systems.

Biomass

6.10 Although assessment is difficult because of serious deficiencies in data, it has been estimated that biomass provides between 6 and 13 per cent of the world's energy,[3] and is by far the main source of renewable energy in the developing countries. Moreover, according to

some experts, biomass in the form of alcohol (fermented from sugars and starch) and biogas (produced from animal and vegetable waste) provides the largest potential substitute for fossil fuels.[4]

6.11 Biomass consists of all combustible plant or animal matter, including wood (and charcoal), straw, husks and dung. It can be converted into energy by direct combustion to produce heat or steam; anaerobic digestion to produce biogas (methane and carbon dioxide); gasification to make 'producer gas'; and fermentation to produce alcohol. Organic materials have been used as a direct source of heat since time immemorial. Since they are likely to remain crucial to the energy needs of millions of people in both the rural and urban areas of developing countries, and because their rapid increase in use has important ecological implications, the technology involved merits serious consideration. The cutting of fuelwood in developing countries is estimated to claim 10 to 15 million hectares of forests each year. This causes soil impoverishment and erosion and in extreme cases, desertification; it thereby lowers agricultural productivity. The amount of fuelwood cut is enlarged by the low efficiency of relevant technologies in current general practice. As a result, large-scale afforestation is required, especially on non-arable or marginal lands, as is the upgrading of wood-burning/charcoal technology. The importance of the latter is apparent from the fact that improved wood-burning stoves can, in theory, approximately halve the energy requirements of the domestic sector; modern techniques of charcoal-making are also capable of effecting considerable savings.[5] In addition, wood and sugar-cane bagasse can be used directly as fuel to generate electricity. In countries such as Brazil and the Philippines, where adequate supplies can be assured, wood-fired electricity generating plants are competitive with diesel-fired ones, and can save valuable foreign exchange.

6.12 Significant developments are taking place in many of the technologies associated with biomass production and conversion. 'Traditional' biotechnology has been used to develop specific crops for energy purposes, and model tree-farms have been developed in a number of developing countries including Kenya, Nigeria and Sudan. But developments in genetic engineering and other areas of 'new biotechnology' are expected to make a greater contribution over the longer term. Higher-energy species can be engineered through recombinant DNA technology, and their supplies increased through molecular cloning. Existing tree-farms suggest that 1,500 hectares are needed to provide one MW of electricity per year. But this could be reduced if new biotechnology processes are used to maximise forestry output. Similar research is being carried out on other potential energy crops, such as sugar-cane, sweet sorghum, cassava, and certain oil-bearing plants, in order to select high-yielding, low cost varieties. Also being considered

as an energy source are fresh and saltwater aquatic plants which have the advantage of not taking up valuable land.[6]

6.13 Biogas technology has recaptured the attention of many developing countries in recent years as a relatively simple and cheap way of producing energy, although its contribution is likely to remain marginal. The gas is used basically as fuel for cooking and lighting, and special purpose-built stoves are already in use in China, India[7] and some other developing countries. It can also be used to power engines for processing crops, pumping water or generating electricity. The gas is environmentally sound, as by reducing the demand for firewood, it improves forestry conservation and reduces soil degradation and desertification. In addition the by-product 'sludge' produced in the fermentation process can, after treatment, be utilised as a fertilizer, as animal feed or for fish farming. The technology is also of particular importance in rural areas which lack adequate organic waste disposal systems, and can lead to improvements in public health. Such integrated bio-systems can be installed and operated in rural areas by few persons at low cost and with only routine maintenance. The main problem is that the cost of the equipment and quantity of raw material (waste from, say, four or five animals) may be beyond the means of the average family in most developing countries. Increasing use of biogas technology in rural areas has also the drawback of making the landless poor still poorer by reducing their supply of free fuel (wood and dung). In addition, as the organic substitute used must be mixed with water (up to a maximum solids content of about one-sixth), the availability of water could be a constraint in certain locations.

6.14 Producer gas can be used to generate shaft-power and heat. One of its major attractions is that it can be consumed in virtually any type of internal combustion engine: with relatively simple adjustment, gasoline engines can be converted to run entirely on producer gas. It can also supply heat for glass-making, brick-making, brewing, fertilizer production, etc. Countries with large forest resources are obviously well endowed for making producer gas, although it is highly toxic, needs careful handling and has the added disadvantage of producing a tarry, corrosive by-product when more efficient conversion techniques are employed. New technology is being developed, however, which could make it safer and more efficient.

6.15 The supply of alcohol fuel (methanol and ethanol) is limited by the large amount of wood or crop surpluses needed for its production. And since at present micro-organisms are relatively inefficient in converting the feedstock to alcohol, the ratio of energy produced by the process to that consumed in it may be as little as 1:1 (especially if the energy cost of planting and harvesting the feedstock is taken into

account); it is possible, however, to reach a ratio of 8:1 by using sugar-cane residues and by-products. Production of ethanol from sugar, molasses and starches, for use as a substitute for petrol in transport and as a feedstock in the chemical industry, is the most important recent application of alcohol. Cars with engines adapted to burn fuel containing 15–20 per cent ethanol have for some time been common in Brazil (where by 1984 ethanol production had reached 100,000 barrels per day, costing US$40 per barrel[8]), and engines have now been designed to use pure ethanol. It had been planned that by the year 2000 all cars in Brazil would be run on alcohol, but falling real prices of petroleum mean those targets may have to be adjusted. Several other countries, including the United States, Costa Rica, Malawi, Kenya and Zimbabwe, have also embarked on alcohol production for use as a petrol substitute or chemical feedstock.

6.16 Although alcohol increases fuel efficiency by raising the octane-rating, corrosion had been a problem for ethanol-fuelled engines: this has been largely solved by nickel-plating the carburettors. A further difficulty is that ethanol has only a single flash-point and must therefore reach the car engine's combustion chamber at precisely the right temperature. Methanol is difficult to integrate with petrol for use in vehicles, and is more expensive to produce than ethanol.

6.17 Research in genetic engineering aims (*inter alia*) to increase the efficiency of microbial breakdown of cellulose in order to facilitate the direct conversion of cellulose waste into methane.[9] This may provide a more efficient route to methane and methanol production, and Canada's National Research Council has been engaged in identifying suitable micro-organisms to convert forestry wastes into methane.[10] It has also been suggested that an exchange of genes between yeast and organisms that degrade cellulose could lead to the production of ethanol from plant wastes.[11] These approaches remain at the R & D stage, however, and are not expected to have any commercial application this decade.

Hydropower

6.18 Hydropower is by far the largest commercial source of renewable energy. It is used mainly for generating electricity, of which it accounts for almost one-quarter of the world's total, although its associated dams are also used for irrigation, flood control and water supply. Its limitations include site specificity, heavy capital outlay and long lead times, while variations in water-flow can cause fluctuations in energy supply. Moreover, large reservoirs can harm the environment, resulting in loss of human habitats, fisheries, farm and wood lands, as well as wild-life; they can also cause soil erosion.

6.19 Despite these problems, the growth of hydropower continues. The potential is huge and according to estimates by the World Bank,

only about one-sixth of the world's reserve is being utilised. Developing countries possess about half this resource base and only one-tenth had been developed by 1980. Forecasts suggest that hydro-electricity generation could be at least doubled by the year 2000. In the last quarter of this century, developing countries (excluding China) are expected to increase their hydro-electricity output fourfold, and to raise it a further two and a half times by the year 2020.[12] Large projects planned, underway or in operation in developing countries include the Guri project in Venezuela, Yangtze Gorge in China, Itaipu scheme in Brazil, Qattara Depression in Egypt and Mahaveli scheme in Sri Lanka.

6.20 Indigenous technology for hydro-electricity generation exists in only a few developing countries, including China, India, Brazil and South Korea. Mainly because of low operating and maintenance costs, electricity from large and medium sized hydroplants is cheaper than that from coal, petroleum or nuclear-fired stations. Small turbines are still generally less efficient than large ones, but technical developments have raised their efficiency and new designs for low 'heads' are being developed. When electricity from thermal plants is already available, mini-hydro stations (under one MW) can supplement supplies, reduce average costs and enhance self-sufficiency. Mini-hydro projects are estimated to comprise 5 to 10 per cent of the world's currently harnessed hydro resources; with the advantage of relatively low capital costs and a non-pollutant nature, and given likely further improvements in the efficiency of turbines, mini-hydropower is expected to grow in popularity in developing countries.

Solar energy

6.21 Technology for producing solar energy can be divided into two main categories: solar thermal technology, which traps sunlight in collectors and transforms it into heat or electricity through solar engines; and photovoltaic (PV) energy conversion technology, which harnesses solar rays directly to generate electricity using solar cells.

6.22 The technology embodied in solar collectors is fairly simple and costs have been reduced markedly although they are still high for mechanisms such as sun tracking devices which increase the collector's efficiency. The efficiency of solar collectors is expected to increase considerably in future, especially with the use of chemical salts instead of water for storing solar heat. Plant for solar thermal electricity generation ranges in capacity from 10 kW to several MW, but the efficiency of small-scale plant is low and such devices have not met with widespread acceptance in developing countries. Solar energy is increasingly being applied for space heating, water heating and air-conditioning in developed countries, and for drying wood and agricultural crops in developing countries. Other devices which are currently

available include solar cookers (not yet widely used because of technology problems), solar stills for water desalination, solar ponds for domestic space heating and electricity generation, and solar water pumps for irrigation; solar furnaces (heliostats) for electricity generation are being developed in a few industrial countries.

6.23 PV technology is mainly in the hands of large multinational companies and has benefited from development grants by industrial country governments. The PV systems they have developed can operate over a wide range of capacities and have several important applications. Their portability and freedom from utility linkages make them specially valuable where remote power requirements need to be met, as in communications (power telephones and repeater stations, radio transmitters on mountain tops), navigation (power warning beacons on oil drilling platforms), and geological surveys (in remote-sensing equipment). The PV systems can also generate electricity for use in isolated villages and power irrigation pumps, although in general they have not yet proved cost-effective in these applications. Although the cost of PV systems, currently estimated at about US$7 per peak watt, is still prohibitively high and has not fallen as sharply as anticipated, these systems could become competitive with oil-fired or nuclear-fuelled electricity generation plants in developed countries by around the year 2000, when solar power could meet about 5 per cent of the world's energy needs. This, however, depends on increasing the conversion efficiency of solar cells (possibly by the use of germanium) and improving the crystallisation process.

Wind energy

6.24 Windmills are highly site-specific and, as an energy source, generally unreliable. Their use has therefore been concentrated in those activities, such as pumping water, where discontinuity is least critical. Though of great antiquity, their widespread use in developing countries has been inhibited by high cost (in comparison, say, with diesel pumps) and design unsuitability for small-scale manufacture. As a result, present production is probably only about a tenth of the potential world market of 50,000 units per year. But considerable R & D is taking place and some results appear promising. For example, a three ton wind-pump capable of lifting water from 200 metres has been developed which is claimed to last five times as long as a diesel engine and to cost half as much. Ninety of these pumps are presently in use, mainly in Kenya and Pakistan.[13] In Peru, some 2,000 locally-designed and manufactured wind-pumps have been installed in one region to raise irrigation water,[14] while new types of sail windmills have been designed in India, Colombia and Ethiopia. Yet, although wind energy may seem attractive in certain rural areas and small islands, the lack

of mechanisms to demonstrate these technologies and of expertise to evaluate and exploit them means that the large-scale use of wind pumps and power units in the developing countries still appears remote.

6.25 The use of onshore winds to generate electricity for grid linkages is being actively developed in the industrial countries. Most of the countries have wind-power programmes, and progress has been such that systems (mainly between 50–100 kW) are often regarded as economically attractive in remote locations, especially when fiscal and financial incentives are taken into account. Possibly the largest installed capacity is in the United States where, in California alone, the capacity of wind farms was 600 MW in 1984 and was expected to reach 1,000 MW in 1985. Many of these are subsidised, however, and their commercial viability is still to be demonstrated. American attempts to make giant commercial wind turbines (over two MW capacity) have so far been unsuccessful, although a British consortium is on course for completing a three MW turbine in Scotland by 1986.

6.26 There are a number of problems relating to large-scale wind turbines. Their installation and maintenance are expensive while fluctuating wind speed, as well as often strong seasonal dependence, is a further complication. But perhaps the major drawback, in industrial countries at least, is their lack of environmental acceptability on grounds of noise and visual intrusion. Even so, wind energy is environmentally safer and cleaner than nuclear or fossil-fuelled electricity plants.

Geothermal energy

6.27 Geothermal energy is contained in the natural heat under the earth's surface; technologies have been developed for tapping three of the six systems (dry-steam fields, hot-water fields, and low-enthalpy fields) and are at the R & D stage for the others (magma energy, geopressurised zones and hot dry rocks). Hot-water fields are the most commonly exploited, but dry-steam fields have the advantage that steam can be used directly in generating electric power.[15] The actual production technologies are relatively mature, being akin to the petroleum industry. Among the problems encountered is the production of hydrogen sulphide.

6.28 Although geothermal resources are widely distributed, relatively few sites have been exploited, both because alternative sources of energy have been cheaper and because the energy can often be used only in close proximity to where it is being tapped. The main economically recoverable resources are to be found in the western part of the American continent, a band from South-east Europe to the East African Rift Valley, and an area from South-east Asia to the Pacific islands.[16]

6.29 Geothermal energy can be used for space heating for residential, commercial or agricultural purposes, hot water supply, process heat, and electricity generation. With the rising price of fuel oil in the 1970s, geothermal electricity generation became increasingly economical in several countries. Although the capital costs of geothermal electricity generating plants are high (in 1980, the World Bank estimated them at $1,000–2,400 per kW, compared to $400–1,200 for coal or diesel-fired plant), operating costs are lower than for most nuclear and oil-fired plant.

6.30 In the Third World, geothermal electricity generating plants have been established in China, El Salvador, Indonesia, Kenya, Mexico and the Philippines. In the industrial countries, they exist in France, Hungary, Iceland, Italy, Japan, New Zealand, USA and USSR. Worldwide, installed capacity was estimated at 1,800 MW in 1980.

Ocean energy

6.31 The only technology which has been commercialised to exploit ocean energy is that to harness the tides.[17] A tidal plant of 240 MW has been operating in France since 1966. Capital costs of this type of plant were estimated in 1980 at $1,500 per kW (compared with $400–1,200 for coal or diesel-fired) and generating costs at about $0.08 per kW. Small-scale tidal plants have been built in China and the Soviet Union, while a few other countries are undertaking feasibility studies. However, it is believed that, worldwide, there are no more than 40 sites which might eventually be used for generating electricity through this means.

6.32 The exploitation of ocean thermal energy conversion has only reached the pilot stage. The system used is related to the solar pond concept, although the smaller differences in temperature (around 20°C) lead to low efficiencies and the need to pump very large quantities of sea-water. While the technology has been demonstrated technically, its economic viability has yet to be proven.

6.33 Despite the large number of designs for harnessing wave-power, no breakthrough has yet occurred, though some developed countries are continuing R & D.

Integrated energy systems

6.34 The use of a single source of renewable energy may not provide a reliable and continuous supply or, on its own, be technically efficient and cost-effective. A combination of several of them may, however, rectify these deficiencies. Countries are therefore beginning to adopt integrated approaches to energy. Demonstration projects already exist.

For example, at a UNEP-assisted project in a Bangladesh village, animal waste, solar radiation and wind power are being utilised to provide energy in various forms: biogas for cooking, solar power for pumping (drinking water and irrigation), and wind power for generating electricity.

III. ECONOMIC AND SOCIAL IMPACT

Economic aspects

6.35 The relationship of increases in energy consumption to economic growth varies substantially, from one country and time to another, but it remains generally true that increasing supplies of energy are a prerequisite for an expanding economy. This is especially true of developing countries, whose growth of commercial energy consumption has significantly outstripped that of GDP.[18] The reason is to be found partly in the substitution of 'commercial' for 'non-commercial' energy but mainly in the growth of the industrial sector, particularly of 'heavy' industry.

6.36 Although economic development requires the balanced growth of all sectors, the key to economic growth has generally been found in industry, especially manufacturing. Industrial development requires the ready availability of heat, mechanical energy and electrical energy. High-grade heat, especially important for the operation of process plant, notably in metal smelting, is not readily obtainable direct from renewable sources of energy, except in the case of some sources of geothermal energy. Lower-grade heat, suitable for some industrial applications, can be obtained from sunlight (through the use of solar thermal technology, as in solar engines), from biomass (through direct combustion or anaerobic digestion/gasification or alcohol fermentation) and from fuelwood/charcoal.

6.37 Mechanical energy can be readily obtained from wind, water and draught animals. In this form it is generally more suitable for small-scale 'light' industry, such as processing agricultural products, than for 'heavy' manufacturing. Electrical energy is a key input, not merely for manufacturing but for mining, services and even agriculture. To date by far the most important renewable source of electricity generation has been water (to drive turbines); though other sources, including the sun (through solar thermal technology and PV energy conversion technology) and the wind (through aerogenerators), are being increasingly employed, their contribution is still only marginal.

6.38 Apart from well-known large-scale hydroelectric projects, the main impact of renewable energy in developing countries has so far

been felt in the agricultural and household sectors, especially in the rural areas. In some instances relatively simple improvements to the technology can make big differences to the welfare of the users. Examples include more efficient wood-burning stoves, biogas converters, and windmills and watermills. As far as transport is concerned, one of the most notable recent developments has been in the use of alcohol as an additive to motor spirit in Brazil.

6.39 The greater use of energy—including that from renewable sources—will clearly have a positive (if unquantifiable) impact on overall employment. In so far as many renewable sources are widely available, the energy they produce can help to stimulate decentralised activities, and thus encourage rural development and generally facilitate the implementation of regional policies. The ability to generate electricity on a small-scale, local, yet economic basis, through the greater use of, say, solar, wind or biomass energy, rather than to bring it into a region through expensive long-distance transmission lines, should be particularly helpful in this respect.

Social aspects

6.40 Acquisition of technologies to produce renewable energy has social as well as economic effects. In the medical field, for example, reliable supplies of potable water are basic to improved health: solar stills to desalinate water are already being used in a few countries and are likely to be introduced into others. The installation of biogas digesters can improve nutritional standards and therefore health, through the enhanced crop and animal yields which result from using the fertilizer or animal feed produced from the by-product 'sludge' created in the fermentation process.

6.41 Renewable energy technologies can also have considerable environmental and ecological effects. For example, in the generation of electricity, the substitution of solar cells or panels in place of fossil fuels reduces pollution, while that of solar or wind energy in place of wood reduces deforestation and therefore soil erosion and the risk of desertification. On the other hand, the use of aerogenerators is visually and acoustically intrusive, while the construction of large reservoirs for hydro-electric generation can cause losses of human and animal habitats, climatic changes and soil erosion. Perhaps most important of all are the effects of the still fast increasing use of fuelwood. In developing countries this is estimated to claim 10-15 million hectares of forest every year. It has caused widespread soil impoverishment and erosion, and in extreme cases, even desertification; it has also reduced agricultural productivity. Rectifying the damage needs not only large-scale reafforestation but a further upgrading of wood-burning and charcoal-making technology (particularly of stoves in the household sector).

6.42 The greater utilisation of renewable energy technologies also has effects—actual and potential—on the structure of societies. To the extent that these technologies can be economic at low levels of energy output, and in so far as they depend on elements which are widely available—for example biogas digesters at present and perhaps PV systems in future—they can help societies to decentralise and curtail the drift from rural to urban areas.

IV. PROBLEMS AND POTENTIALS FOR DEVELOPING COUNTRIES

6.43 Some developing countries are comparatively well supplied with renewable energy resources, especially solar and biomass, although many countries do not have the space to make great use of them. These resources are particularly suited to meeting the needs of dispersed populations in rural areas for decentralised sources of energy in small amounts, and may prove much more cost-effective than in the industrial countries. Nevertheless, because of a number of constraints, some of which are outlined below, it is unlikely that most renewable energy technologies will be sufficiently developed and diffused to make a major contribution to the energy supplies of developing countries this century. In the meantime, however, individual countries may still benefit significantly, while the impact of renewable sources of energy on particular locations and ways of life can be substantial.

6.44 The ability of developing countries to exploit their renewable energy resources depends largely on their own capacities. Mastering the different technologies requires varying degrees of scientific knowledge and skill, but a basic requirement is an ability to undertake energy planning and assessment. Here the major stumbling-block is the inadequate data base on such factors as wind velocity and variation, water flow and seasonality, and insolation and cloud cover, to which these energy sources are highly sensitive. Regarding the operational technology, most newly industrialising countries can produce small hydro units, biogas digesters, bio-fuels (ethanol) and windmills; they can also assess, acquire, instal and operate the more sophisticated technologies for PV systems, large hydro-plant, aerogenerators and geothermal equipment. But many other developing countries lack the knowledge, skills and other resources to instal and operate even some of the less sophisticated renewable energy technologies. These countries need more help from the international community to strengthen their national capabilities to select and adapt existing technologies. In particular help is needed with R & D programmes undertaken either on a national or,

where possible, regional or wider collaborative basis, as well as in the diffusion of the resultant products and processes.

6.45 Cost and other factors continue to inhibit both the development and the use of renewable energy technologies, including in certain regions even the more mature ones. For example, a major factor in determining the viability of biomass conversion projects is the net energy ratio,[19] which for some feedstocks has been found to be less than or approaching 1:1. The cost of producing biomass feedstocks is equally crucial. Such feedstocks have many competing uses; for example, instead of being used to produce energy, sugar and starch crops can be eaten, wood can be used for construction or paper-making, and dung for fertilizer or brick-making. The energy, food and raw material potential of biomass has therefore to be considered in an integrated way, in line with the particular needs and resources of individual countries.[20]

6.46 Reliable information on the comparative costs of different renewable energy technologies is difficult to obtain, and generalisations have to be made with caution, since location-specific factors affect development and operating costs considerably. However, a broad estimate of the costs of energy from different sources, made by the World Bank in 1980, indicated that a number of sources of renewable energy were then at or near the cost of imported crude oil.[21] If their production technologies were given adequate financial and other support, they could be used more extensively, contributing to the development of the countries concerned and saving some of their scarce foreign exchange. Provided the technologies for producing, transporting and utilising renewable energy are readily available at competitive costs, the potential for these energy sources seems to be bright.

6.47 How appropriate they are to the development efforts of the countries concerned, depends on the nature and objectives of the countries themselves, at least as much as on the technical characteristics of the energy source. In countries with small and dispersed populations, mini-hydro schemes, small-scale biogas digesters, solar crop driers, solar waterheating/pumping systems, and more efficient wood-burning stoves usually contribute more to improving the quality of life than do large-scale hydro projects, which often are economical only if the surplus electricity can be exported. In small island economies, wind, and sometimes geothermal resources, offers scope for supplementing energy produced from biomass and solar technologies, while eventually ocean thermal energy conversion technologies might conceivably become applicable. Large developing countries can often benefit from a greater mix of renewable energy sources, including large-scale hydro and, in a few cases, the generation of electricity from biomass.

6.48 The great variations in developing countries' natural characteristics (topography, climate etc.), technical capabilities and financial resources, mean that considerable thought has to be given to deciding the most appropriate mix of policies to optimise the use of energy supplies. This will often require assistance from the more technically advanced countries. Opportunities for technicians, technologists and policy-makers to see, at firsthand, how other countries seek to overcome their energy problems would doubtless be instructive and should be encouraged.

NOTES*

1. UN, Preparatory Committee for the Conference on New and Renewable Sources of Energy, Third Session, *Synthesis of Technical Panel Reports,* New York: March 1981 (A/CONF. 100/PC/42).
2. UN, Report of Secretary-General, *Activites and Financial Flows in the Implementation of the Nairobi Programme of Action,* Committee on Development and Utilisation of New and Renewable Sources of Energy, Second Session, New York: April 1984 (A/AC. 218/5, Table 5).
3. UNIDO (1982) ID/WG. 384/6/Rev.1.
4. Heden (1981).
5. In India, 132 million tons of wood, 41 million tons of agricultural waste and 70 million tons of dung were reportedly used as fuel in 1978. With new stove designs, it has been estimated that no more than 85 million tons might be needed to meet current requirements. (K. Prasad, *Wood-burning Stoves: their technology, economics and develoment,* ILO Working Paper, 1983.)
6. UNIDO (1982) ID/WG. 384/6 Rev.1.
7. In one province of China alone there are reportedly over seven million gas digesters in operation. In India it was planned to bring in 150,000 digesters in fiscal 1984–85, with a 50 per cent subsidy of costs up to Rs. 3,000.
8. *OPEC Bulletin*, June 1984.
9. Narang (1981), para. 63.
10. Heden (1981), p. 21.
11. Narang (1981), para. 64.
12. World Energy Conference, *Annual Report,* 1980.
13. *The Economist,* 16–22 February 1984.
14. *Vita News,* July 1982.

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

15. *Energy for Development: an International Challenge,* North-South Roundtable of the Society for International Development, New York: Praeger, 1981, p. 48.
16. M. Fritz, *Future Energy Consumption of the Third World,* London: Pergamon Press, 1981, p. 88.
17. This section is based on UN (1981) A/CONF. 100/PC/42.
18. Between 1960 and 1980 the average annual rates of growth of commercial energy consumption and of GDP were 6.5 per cent and 5.5 per cent, respectively, in developing countries. By contrast, they were 3.3 per cent and 4.2 per cent, respectively, in developed market economy countries.
19. The net energy ratio is the energy output of useful products divided by the energy costs of agricultural processing and of inputs (such as fertilizers or pesticides).
20. UNIDO (1982) ID/WG. 384/6/Rev.1.
21. World Bank, *Energy in the Developing Countries,* August 1980, Table III.1.

Appendix 7

ILO Recommendation on Employment Policy, 1984[1]

Part IV Technology Policies

'One of the major elements of national development policy should be to facilitate the development of technology as a means of increasing productive potential and achieving the major development objectives of creation of employment opportunities and the satisfaction of basic needs. Technology policies should, taking into account the stage of economic development, contribute to the improvement of working conditions and reduction of working time, and include measures to prevent loss of jobs.

'Members should—

encourage research on the selection, adoption and development of new technologies and on their effects on the volume and structure of employment, conditions of employment, training, job content and skill requirements; and

encourage research on the technologies most appropriate to the specific conditions of countries, by ensuring the involvement of independent research institutes.

'Members should endeavour to ensure by appropriate measures—

that the education and training systems, including schemes for retraining, offer workers sufficient opportunities for adjusting to altered employment requirements resulting from technological change;

that particular attention is given to the best possible use of existing and future skills; and

that negative effects of technological changes on employment, working and living conditions and on occupational safety and health are eliminated to the extent possible, in particular through the incorporation of ergonomic, safety and health considerations at the design stage of new technologies.

'Members should, through all methods suited to national conditions and practice, promote the use of appropriate new technologies and assure or improve liaison and consultation between the different units and organisations concerned with these questions and the representative organisations of employers and workers.

'The organisations of employers and workers concerned and undertakings should be encouraged to assist in the dissemination of general information on technological choices, in the promotion of technological linkages between large-scale and small-scale undertakings and in the setting up of relevant training programmes.

'In accordance with national practice, Members should encourage employers' and workers' organisations to enter into collective agreements at national, sectoral or undertaking levels on the social consequences of the introduction of new technologies.

'Members should, as far as posible and in accordance with national law and practice, encourage undertakings, when introducing into their operations technological changes which are liable to have major effects upon workers in the undertaking—

to associate workers and/or their representatives in the planning, introduction and use of new technologies, that is to inform them of the opportunities offered by and the effects of such new technologies and to consult them in advance with a view to arriving at agreements;

to promote a better organisation of working time and a better distribution of employment;

to prevent and mitigate to the greatest extent practicable any adverse effects of the technological changes on workers; and

to promote investments in technology that would encourage, directly or indirectly, the creation of employment and contribute to a progressive increase in production and the satisfaction of the basic needs of the population'.

NOTE

1. Extract from text (paragraphs 20–26 of original) of ILO Recommendation adopted in 1984.

Appendix 8

A Consultant's Note on New Technology Agreements[1]

The main features of 'best practice' approaches contained in new technology agreements may be summarised as follows:[2]

Procedurally, the agreements typically specify:

—the commitment of both management and trade unions to the introduction of new technology and the satisfactory management of change;

—the provision of information by management to the trade unions on the introduction of new technology, at an early stage, before decisions are taken and when final choices can be influenced. The information should allow for transparency with regard to the effects of changes and the choices to be made;

—the establishment of management/trade union bodies to discuss, monitor and negotiate change;

—the opportunity for the election and training of trade union representatives with specific responsibilities for monitoring the introduction of new technology, but with close links to the membership;

—the possibility of access by the trade union in a plant to outside expertise, in some cases paid by, although independent from, management;

—the establishment of a procedure for monitoring and regulating the collection of personal data on individuals working in a plant and for regulating its use; and

—the inclusion of a 'status quo' clause whereby the trade unions have the right to veto changes unless they are agreed.

In terms of the substantive issues regulated by these procedures, new technology agreements typically specify that:

—there should be 'no redundancies' as a result of the introduction of new technology. In some cases, trade unions have even been able to ensure that there should be no reduction in the volume of employment;

—staff whose jobs are changed or eliminated due to technological change should be retrained and given jobs of comparable status in the same enterprise. Downgrading should be limited;

—for older workers, voluntary schemes of early retirement should be introduced and, in general, working time should be reduced to ease employment problems;

—the introduction of new technology should not be used to increase the pace of work, control and supervision or to reduce job contact or lead to a higher incidence of shift working;

—the health and safety aspect of working with computerised equipment and visual display units (VDUs) should be closely regulated; the design of the equipment and working place should conform to ergonomic standards; the amount of time spent working with VDUs should be limited; regular breaks away from the machine should be provided; and regular medical check-ups made available;

—the personal information collected on employees should be strictly limited to that relevant to the activities of the company; and

—the pay of displaced workers should be guaranteed; new grading should be introduced for those operating new equipment, but it should not be used to increase pay differentials.

These points might be taken to represent a code of good practice in introducing new technology. It is clear that the particular form of agreement or approach needs to be adapted to national circumstances. Table 8.1 summarises the way in which technological change has been regulated at the workplace in several developed countries. As can be seen, in some countries legislation has laid down basic trade union rights to deal with change, such as the work environment and co-determination laws in Sweden. Elsewhere custom and practice or general framework agreements have laid down rights, such as in Norway and Denmark. In some sectors, including printing, sectoral agreements are the norm, whilst in others company-level or local agreements covering technology have become increasingly widespread (for example in Germany (FR) and Britain). In developing countries, particular attention needs first to be given to establishing and developing free trade unions, and to developing training and education to equip the workforce and

Table 8.1

Summary of Procedures of Joint Regulation of Technological Change in Selected Countries

Country	*Unionisation rate (%)*	*Laws used*	*Collective agreements*		
			National framework level	*Sectoral level*	*Company or plant level*
Germany (FR)	40	Works Constitution Act 1972 Works Safety Act 1973 & regulation on work with VDUs 1981	None	Job protection agreements in metalworking, textiles, footwear, leather, paper processing, printing	Upwards of one hundred agreements concluded
United Kingdom	50	Health and Safety at Work Act 1975	None	Parts of public sector	Upwards of one hundred agreements concluded
Norway	45	Working Environment Act 1977 & regulation on work with VDUs 1982	Agreement on computer-based systems 1975	Banking	Most of industry and services covered by local agreements
Denmark	70		Agreement for private sector 1981	Banking/public sector	
Sweden	73	Working Environment Act 1978 & regulation on work with VDUs 1981 Co-determination Act 1977	Work environment agreement 1976	Technology agreement in the printing sector, co-determination agreements in central government, local government, private sector	Use of legislative rights
Italy	43	Statute of Workers Rights 1970 Health and Safety Act 1978	None	Clauses included in sectoral agreements on metalworking	Clauses included in several company agreements, e.g. Fiat, Olivetti, Alfa Romeo

Belgium	75		Collective agreement on new technology 1983	Printing	Local agreements implementing national agreement
United States	20		None	Technical change clauses in general agreements	
Australia	45	Unfair dismissal legislation	None	Telecommunications	Agreements in parts of printing and public sector
Canada	30	Recommendations for legal rights	None	Limited clauses in existing agreements	
Japan	25		None	Telecommunications	Plant committees
Other countries		Health & safety legislation (e.g. France); co-determination legislation (e.g. Austria)	None	Printing sector in the Netherlands, Austria, Greece	

its representatives with the expertise to handle the issues raised by technological change.

NOTES

1. John Evans, European Trade Union Institute, Brussels. For an elaboration see Evans (forthcoming).*
2. For a more extensive 'model' agreement, see that published by the International Federation of Commercial, Clerical, Professional and Technical Employees (FIET), Geneva, 1983.

* See also Appendix 10, Selected Bibliography.

Appendix 9

United Nations Activities in Science and Technology Under the Vienna Programme of Action

9.1 The Vienna Programme of Action, adopted by the United Nations in 1979, has three major objectives:

—to harmonise the extensive, and often overlapping, activities of all UN agencies in eight areas of science and technology;[1]

—to strengthen developing countries' indigenous scientific and technological capabilities; and

—to restructure the existing pattern of international scientific and technological relations.

While underlining the need for developing countries to implement their own national plans, the Programme recognises the importance of collective action by these countries, and of supportive measures by developed countries to create a suitable environment for their efforts. It also recognises the role that can be played in this area by the international community through the multilateral organs of the UN system. Some examples of activities in these organs in the eight areas of the Vienna Programme are annexed (pages 98–105).

9.2 There have been continuing problems in coordinating and financing the work of the United Nations in science and technology (S & T) under the Vienna Programme. Despite the efforts of the Intergovernmental Committee on Science and Technology for Development (ICSTD) which was established to oversee the Programme, a review of UN activities in 1982 and 1983[2] found that there was still a need to improve coordination of agencies' activities in S & T. It therefore recommended the compilation of a directory of major UN S & T information services, as well as a data base on all other UN activities

in this field. In addition it identified several other areas where work was needed.

9.3 Funding has been a major constraint. The latest information shows that the extent of different UN bodies' financial involvement in S & T has varied considerably but that, in total, under a tenth of all UN expenditure was directed to S & T. Some two-thirds of this was spent on training and the application of new technologies; other equally important activities, such as making more efficient use of existing skilled manpower or assistance with policy-making, industrial research and technology, natural resources and basic sciences, received much smaller proportions. Under the Vienna Programme a special fund—the UN Financing System for Science and Technology for Development (UNFSSTD)—was launched to boost resources for UN activities in this area. The developing countries wanted a fund equivalent to between one and two per cent of annual global expenditure on S & T (estimated at $100 billion as far back as 1979), but lack of support from the developed countries restricted it to a much lower amount, to be raised by voluntary contributions. Pledges to date have been well below the $300 million target for 1983–85 established in 1979 by the Vienna Conference; in 1983 (the latest data available) the overall amount was barely $45 million. The fund has only been able to finance 100 projects, out of more than 900 requested. UNFSSTD's long-term viability remains uncertain, and a considerable increase in pledges is needed if the UNFSSTD secretariat is to be financed beyond 1985.

NOTES

1. Viz. development and assessment of science and technology policies; indigenous infrastructure; choice and transfer of technology; human resources; information; research and development; international cooperation; and finance. Some examples of UN work in these eight areas are annexed below.
2. United Nations, *Biennial review and appraisal of the activities of the United Nations system in the field of science and technology for development*, New York: March 1984 (A/CN 11/45).

ANNEX

Some UN Activities in the Eight Areas of the Vienna Programme

I. S & T Policies and Plans

UNCTAD	Technology policies; legal and institutional

	framework relating to transfer of technology; industrial property rights; advisory service—technical assistance with policy-making, training, exchange of information.
UNIDO	Seminars on industrial technology policies and planning; advice on institutional arrangements for acquiring foreign industrial technology and services.
UNEP	Advice on managing environmental impact of technological applications.
ESCAP	Studies on bilateral technology agreements.
UNFSSTD	International conference on S & T policy and research management.
UNESCO	Assistance with identifying priorities in science education, training, research; creation of regional networks of research on social factors affecting scientific development.
ILO	Studies on role of technology choice in development; assessment of technology policy.
FAO	Technology policies designed to achieve food security.
World Bank	Assistance with formulation of science policies and strategies for industrial technology development.
WHO	Formulation of national drug policies.
WIPO	Model law on inventions for developing countries; assistance with handling patent applications and preparing patent legislation.
UNCSTD, UNIDO, UNCTC, ILO, FAO/IFAD, FAO/IAEA	Advising policy-makers on likely impact of new technologies on various sectors.

II. Creation and Strengthening of S & T Infrastructure

DIESA	Infrastructure aspects of marine resource development.
DTCD	Programmes for energy development, cartography, remote-sensing and statistics.
UNIDO	Single and multipurpose industrial institutes.
UNCTAD	Strengthening institutes dealing with transfer, use or

	development of technology.
UNEP/UNESCO	Microbiology resource centre; network of various training institutions in environment issues in Latin America and the Caribbean.
UNFPA	Assistance to strengthen local institutions' capability in demographic research, training, data analysis.
ESCAP	Advisory services for development of infrastructure and training in various fields.
ECLA, ECA	Seminars on various aspects of technological infrastructure.
UNFSSTD	Projects for the development of technological infrastructure and skills.
UNESCO	Strengthening research and training institutions.
ILO	Assistance with development of rural technology centres; services of its International Centre for Advanced Technical and Vocational Training and three regional training centres.
FAO/IFAD	Development of facilities for agricultural research, both internationally and nationally.
WHO	Development of capability for health research and training.
WIPO	Seminars on setting up patent offices.

III. Choice, Acquisition and Transfer of Technology

DIESA	Studies on choice in marine technology, technologies for coastal erosion control, energy technologies.
DTCD	Technological options in new and renewable sources of energy, application of remote-sensing, non-conventional uses of water.
UNEP	Environmental implications of technological practices in various sectors.
UNICEF	Technological choice in food processing.
UNIDO	Technology transfer in mineral processing, microelectronics and other industrial branches, biotechnology and genetic engineering; operates system for countries to share information on technology agreements; assistance to technology regulation agencies; technical assistance with technology selection and contract negotiation.

UNCTAD	Sectoral studies on technology choice (food processing, capital goods, energy); legal framework and transfer of technology.
UNCTC	Technology transfer in selected capital goods branches; technology choice and activities of TNCs in automobiles, agricultural machinery, and semiconductor industries.
ESCAP	Advice on legal aspects of technology transfer and strengthening national negotiating capabilities.
ARCT, RCTT, ECLA	Regional meetings on technology choice and experience.
FAO	Field trials of appropriate agricultural technologies, both production and processing, including (with IAEA) isotope and radiation techniques.
World Bank/ UNDP	Studies on choice of energy technologies
UNESCO	Studies on water technologies.
ILO	Developmental relevance of technological choice in small-scale industries, rural road construction, rural energy, etc.
WHO	Technology packages for vaccine production; list of essential drugs.
WIPO	Studies on contractual aspects of technology transfer.
ITU	Sets standards for international telecommunications.

IV. Development of Human Resources for S & T

DIESA	Assistance with formulating training programmes for assessment of marine technologies and management of coastal areas.
UNFPA	Training programmes in demographic research; worldwide network for population information.
UNIDO	Training in technology transfer, trends and developments, especially new technologies in various industries.
UNEP	Postgraduate training courses in toxicology, management of the environment; network of training institutions on environmental issues.
UNFSSTD	Various training projects.

UNESCO	Improvement of curricula for engineers; specialist courses in various fields (ecology, oceanography etc.); proposal for an international institute for training and research on S & T policy and planning.
FAO	Training of agricultural research and extension personnel; assessment of needs and facilities for trained manpower in Africa.
ILO	Vocational training programmes; studies on technological development and women.
WHO	Health fellowships—including health research management.
WIPO	Training workshops on processing patent information.
IAEA	Training in use of radiation, safety in nuclear energy.
IMO	Set up World Maritime University; assistance with regional maritime training institutions.
UNCTAD	Training in contractual conditions in technology agreements; study on measuring 'brain-drain'.
ITU	Introduction of international training standards and exchange of information on telecommunications training.
World Bank	Training on S & T aspects of development at its Economic Development Institute.

V. Financing of S & T

UNESCO	Analysis of expenditure on R & D in S & T.
UNDP	Finances S & T activities of various UN bodies.
UNFSSTD	Provides limited funds for projects.
World Bank	Supports the Consultative Group on International Agricultural Research (CGIAR) and technical assistance programmes for agricultural and rural development.

VI. S & T Information

UNCSTD	Studying feasibility of developing a global information network linking national systems containing bibliographical material and data on technological alternatives and their implications.

UNDP	Information Referral System (INRES).
UNIDO	On-line data base of bibliographic material and scientific research activities in different fields; technology information exchange network for development financing institutions; Industrial and Technological Information Bank (INTIB); Industrial Inquiry Service; Technology International Exchange System (TIES) for information on commercial technology contracts.
UNEP	International Register for Potentially Toxic Chemicals (IRPTC); an International Referral System for Sources of Environmental Information (INFOTERRA).
UNCHS	Bibliographical information on building technologies.
UNFSSTD	Financed establishment of technological information system for subregion of Latin America.
RCTT	Disseminates regular information on new products and processes.
UNESCO	Promotes exchange of information on science policies; has computerised information system on S & T literature, known as SPINES—the Science and Technology Policies Information Exchange System—and has set up a World Information System for Science and Technology (UNISIST); has compiled statistical information on scientific manpower, R & D expenditure; helped to develop information networks in specific fields, for example energy and water sciences, and to set up documentation centres—has a Data Retrieval System for Documentation in the Social and Human Sciences (DARE); training in information handling and application of new information technologies.
FAO	Several information networks; e.g. Interlinked Computerized Processing and Storage System of Food and Agricultural Data (ICS); International Information System for Agriculture Sciences and Technology (AGRIS); Current Agricultural Research Information System (CARIS); Aquatic Sciences and Fisheries Information System (IFIS), as well as various year-books on production and trade.
WHO	Bibliographical and research information on health

	issues, health statistics, in its World Health Information Service (WHIS).
WIPO	Information on patents and industrial property rights; assistance with computerisation of patent documentation.
IAEA	Nuclear information and data in its International Nuclear Information System (INIS).
ILO	Aspects of employment and occupational hazards, embodied in its Integrated Scientific Information System (ISIS) and its International Labour Information System (ILIS).
UNCTC	Role of TNCs in transborder data flows.

VII. Strengthening R & D in and for Developing Countries

DIESA	Research on ocean energy sources.
UNEP	Using remote-sensing to monitor desertification.
UNIDO, UNCTAD	Field research by industrial research and service institutes on technological developments.
UNESCO	Research programme on geology for development in Africa; research on marine science, water resource management; studies on natural hazards.
WHO	Research on tropical diseases.
WMO	Research on tropical meteorology.
FAO	Agricultural research and training carried out by 13 research centres of CGIAR, helping to upgrade research programmes in developing countries; national institutes used to carry out pilot projects and demonstrate improved practices; international research networks set up, for example on inland fisheries, buffalo.
UNDP	Supports research, training, extension activities of International Centre for Insect Physiology and Ecology (ICIPE) and International Fertilizer Development Centre (IFDC).

VIII. Strengthening of Cooperation in S & T Among Developing Countries and Between Developed and Developing Countries

UNDP, UNIDO, UNCTAD	Studies of joint industrial ventures and technology licensing between developing countries.

UNCTAD	Report on institutional and policy issues of cooperative exchange of skills among developing countries.
UNCTC	Study of technology transfer and joint ventures among Latin American countries.
UNIDO	Promotion of cooperation in the development of small-scale industries and cooperation in the transfer of technology between enterprises in developed and developing countries.
ECLA, RCTT, ARCT	Promotion of technological cooperation on a regional basis.
WIPO	Assisting regional cooperation in industrial property administration.
FAO	Support given to several regional and subregional bodies, for example the West African Rice Development Association.

Abbreviations used

ARCT	African Regional Centre for Technology
DIESA	Department of International Economic and Social Affairs
DTCD	Department of Technical Co-operation for Development
ECA	Economic Commission for Africa
ECLA	Economic Commission for Latin America
ESCAP	Economic and Social Commission for Asia and the Pacific
FAO	Food and Agriculture Organization of the United Nations
IAEA	International Atomic Energy Agency
IFAD	International Fund for Agricultural Development
ILO	International Labour Organization
ITU	International Telecommunications Union
RCTT	Regional Centre for Technology Transfer
UNCHS	United Nations Centre for Human Settlements (Habitat)

UNCSTD	United Nations Centre for Science and Technology for Development
UNCTAD	United Nations Conference on Trade and Development
UNCTC	United Nations Centre on Transnational Corporations
UNDP	United Nations Development Programme
UNEP	United Nations Environment Programme
UNESCO	United Nations Educational, Scientific and Cultural Organization
UNFPA	United Nations Fund for Population Activities
UNICEF	United Nations Children's Fund
UNIDO	United Nations Industrial Development Organization
WHO	World Health Organization
WIPO	World Intellectual Property Organization
WMO	World Meteorological Organization

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