
Promoting International Transfer of Environmentally Sound Technologies: The Case for National Incentive Schemes

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Introduction

There is a popular view that technological development is a major source of environmental degradation and that African countries need to be cautious of industrialization. This view has fed on the anti-technology sentiments of the 1960s and has found refuge among environmental groups in Africa. Those who romanticize the mythical bliss of the African peasant or pastoralist persistently argue against technological development. We argue that this partisan view ignores two important aspects of technological development.

First, implementing sustainable-development objectives will require major improvements in economic productivity, which can only be secured through the wise use of technology. Indeed, *Our Common Future* underscored this point when it stressed that technology was a 'mainspring of economic growth'.¹ Secondly, technology is increasingly seen as a major agent of environmental management and improvement. It is against such a background that the use of environmentally sound technologies was recognized by the United Nations Conference on Environment and Development (UNCED) as crucial in achieving sustainable development. Chapter 34 of *Agenda 21* which deals with environmentally sound technology stresses the 'need for favourable access to and transfer of environmentally sound technologies, in particular to developing countries, through supportive measures that promote technology co-operation and that should enable transfer of necessary technological know-how as well as building up of economic, technical, and managerial capabilities for the efficient use and further development of transferred technology'. This paper assesses the incentive regimes for the development of technological capacity in Africa with specific reference to environmentally sound technologies. It argues that much emphasis has been put on the international obstacles to the transfer of environmentally sound technologies, but that the role of appropriate incentive regimes in African countries to facilitate technology acquisition and development has been played down.

The paper stresses that international co-operation in the transfer of environmentally sound technologies will not achieve much unless incentives are introduced at the national level to promote the adoption and development of such technologies. It is reforms in technology-policy instruments

at the national level and complementary international co-operation that will lead to the genuine transfer of environmentally sound technologies to the developing countries.

Technology and Sustainable Development *The New Technological Awakening*

The environmental activists of the 1960s perceived large-scale industrial development as the main source of environmental degradation. As a result, technological development was sometimes seen as a key culprit and an 'anti-technology' attitude developed among environmental activists. The work of E. F. Schumacher in the 1970s promoting 'appropriate technology' provided the activists with alternative perceptions on technological change. The notion of technological appropriateness is now being used widely when discussing the relationship between technology and environment. There is a new awakening to the fact that industrial development is not only vital in improving economic performance in developing countries, but that the transition away from the current dependence on basic agricultural production (with the related destruction of the ecological base) will require a shift towards industrialization and the related service-sector activities.

Most developing countries rely on a narrow range of economic activities and there is widespread recognition that they are unlikely to achieve any significant economic growth unless they diversify their economies. It has been argued that the adaptive policies required by the developing countries to deal with the long-term effects of climatic change are the same as those needed to improve economic stability.

Industrial production, therefore, if undertaken in a sustainable manner, could lessen the pressure on bio-productive resources by offering alternative employment.² The basic technical possibilities for making this transition already exist. Whether these options are adopted will depend largely on the policies and practices as well as the range of incentives available in these countries to promote technological development. In the 1990s, and particularly with impetus from *Our Common Future* as well as the results of UNCED, the world community has recognized the

importance of technological innovation in responding to environmental problems. This has made it possible for the private sector, mainly in the industrialized world, to engage in the promotion of the sustainable-development agenda.³

Technological innovation, which used to be seen largely as a threat to the environment, now offers new opportunities for reducing environmental degradation and promoting sustainable development.⁴ This factor has changed the terms of relations between the industrialized and developing countries. In the 1970s technology transfer was seen as a potential threat to the environment, thereby requiring regulation and control. In the 1990s technology transfer is being seen as a source of opportunities for promoting sustainable development. The challenge, therefore, is how to move from the traditional control of technological flow to new approaches of technology assessment that take environmental concerns into consideration.⁵ The transition towards greater application of environmentally sound technologies is being mediated mainly through research-and-development (R&D) activities.

Research and Development

Probably the most important environmental development in the industrialized countries in the 1990s is the changing character of environmental research. In the 1970s and 1980s environmental research was largely disciplinary and piecemeal in character. More recently, research activities have become increasingly multi-disciplinary and systemic in approach. The role of social-science research is increasing. Despite these changes, official environmental R&D funding in the OECD countries remained low in the early 1990s, often not more than 3 per cent of total government expenditure.⁶ This figure, however, covers only explicit environmental R&D. Because of the interdisciplinary nature of environmental R&D, funding continues to go to projects that indirectly relate to environment. Such implicit environmental R&D, though difficult to quantify, will continue to rise in view of the fact that more research projects are starting to incorporate environmental concerns into their activities.

On the whole, environmental R&D expenditure has remained low in relation to the degree of concern over environmental issues. Support has tended to be national, yet most of the major problems require international research efforts. Part of this may be explained by the fact that most of the research policies formulated in the industrialized countries in the 1980s treated research as a tool for international competition and therefore focused on areas with obvious national benefit.⁷

The share of private-sector funding for environmental R&D in the OECD countries is estimated at 80 per cent, compared to 50–60 per cent for total OECD R&D. This is explained by the shift towards product-oriented

environmental R&D as well as the impact of two decades of environmental regulation. The rise of the 'environment industry' devoted to clean-up operations is on the rise, with a global turnover of US\$200 billion. This market is expected to reach US\$300 billion by the year 2000. At this rate, the environment industry is comparable to the pharmaceutical and aerospace industries, but with higher prospects for growth.

One of the most significant developments in research has been the shift from 'clean-up' approaches towards more comprehensive preventive technological innovations. This reshaping of technology has led to more research investment in low-emission and low-waste technologies—a category that is increasingly being referred to as 'cleaner technologies'. Political considerations, regulatory measures, as well as public awareness are being brought to bear on the direction of technological innovation.

The intensification of basic environmental research is also accompanied by measures to promote the commercialization of such technologies. New institutions are being established, especially in OECD countries, to promote innovation in environmental technologies. In addition, support for collaborative programmes is also increasing, especially in the EEC countries, whose annual expenditure on environmental R&D averaged US\$43 million over the 1981–88 period (or 7.6 per cent of its total R&D budget).

Regional programmes, such as the EEC's Science and Technology for Environmental Protection (STEP), the European Programme on Climatology and Natural Hazards (EPOCH), and the Joint Opportunity for Unconventional or Long-term Energy Supply (Joule) are taking root. These changes, however, should not conceal the fact that in many countries funding for research has not expanded enough to meet economic challenges. In most areas there has been a shift from basic research towards applied research. It has also been argued that the decline in public-sector R&D may undermine support for basic research in areas which do not show obvious and short-term commercial application.

It is expected that technological co-operation will be extended to the Eastern European countries through bilateral programmes. However, co-operation with the developing countries is likely to occur largely in the field of the management of natural resources and the transfer of specific environmentally sound technologies. No major technological-co-operation programmes are envisaged, except in areas covered by international conventions on issues relating to climatic change. It is notable that it has been very difficult to reach viable arrangements on issues relating to technology transfer during the biodiversity convention negotiations.

In the more advanced developing countries, emphasis seems to be placed at two main levels: the development of environmental research and training institutions and support for incremental technological innovations at firm level. It is

expected that training in key areas of environmental research will continue to be a major theme in the developing countries.⁸ This is mainly because the basic scientific knowledge required to embark on significant programmes in technological development or natural-resource conservation is still lacking.

But where such capacity exists, the countries face major challenges in providing the institutional basis for the utilization of such capacity. Institutional development as well as the provision of basic infrastructure for technological innovation will remain a major concern for most developing countries in the next decade. But with well-organized international co-operation programmes it is possible to promote the adoption of environmentally sound technologies in some countries, especially where there is requisite capacity in relevant fields.

But international co-operation is often seen in the traditional context of aid. There is a general view that an increase in the flow of overseas-development assistance would necessarily promote technological development in the developing countries. This view emanates from the assumption that development assistance could be used to cover the royalties that would otherwise be paid to suppliers of technology. First, it should be noted that development assistance is not a major carrier of technology to the developing countries. Even in specific areas of technical co-operation, it is doubtful that aid programmes do make important contributions to technological development.

Secondly, most development-assistance programmes focus on agricultural production, which has less potential for technological development than industrial production. An increase in development assistance without the corresponding shift in focus would simply make available more funds that the developing countries cannot utilize effectively. Increases in aid flow cannot necessarily contribute to technological development.

The general perception of technology in most developing countries is the equipment, skills, managerial competence, and the technical specifications associated with the production of goods. Technology transfer therefore refers mainly to the flow of such production capacity. This limited perception of technology has led to the false view that technological development is inherently an expensive process which must rely on external inputs and financial resources.

It would be wise for developing countries to abandon the use of this term and focus on accumulating *technological capacity*, which is the ability to generate and manage technical change (including the related skills, knowledge, and experience as well as institutional structures and networks). In this respect, technological development is a purposive and dynamic process that builds on period gains and is articulated through specific institutional arrangements or *firms*. It takes concerted and guided efforts and does not simply emerge from the mere act of investing in new production facilities.

Development often starts with the use of publicly available technologies. The more advanced developing countries such as Brazil, South Korea, India, and other newly industrialized countries are more likely than the poorer countries to utilize the environmentally sound technologies available in the public domain. In most African countries 80–90 per cent of the total recurrent budgets of national R&D institutions is devoted to personnel emoluments. Technological transition towards sustainable development is therefore likely to be uneven and will be largely influenced by the existing technological capacity in these countries.⁹

As research and science advance the frontiers of knowledge, it is important to bear in mind that such efforts must not lose sight of the guiding principles of sustainable development. Indeed, '[s]cience—like art—is a listening-post at the outer edges of human perception. But science cannot work in isolation. For science to make maximum impact on the societies of tomorrow, it must interact with politics, with democratic debate, and it must be geared towards defined goals'.¹⁰

The current efforts to integrate environmental considerations into all spheres of human endeavour will also influence the character of environmental research. It is likely to fade away as an explicit sectoral activity as other research programmes incorporate environmental objectives into their work. Other fields such as science-and-technology policy will also have to take on the challenges of sustainable development.¹¹ So far this field has been slow to respond to the challenges, a sign of the slow rate at which institutions have responded to the issue.¹² In addition to technological innovation, the pervasiveness of information technology is facilitating the diffusion of knowledge on environmental management. The growth in information networks and databases will assist greatly in the promotion of ideas on sustainable development. Countries that do not have easy access to such facilities are likely to be 'isolated' from the development and to face difficulties in implementing sustainable-development policies.

Ecotechnology Assessment

In a recent study, Vernon states that developing countries 'that develop a strong internal capacity to search out and evaluate foreign technologies are usually able to acquire the technologies they need on satisfactory terms. Those that fail to search and evaluate, however, can make costly errors.'¹³ Technology assessment has emerged as an important discipline whose aim is to evaluate the prospects and risks associated with particular technologies.¹⁴ This is one of the areas that African countries have paid the least attention to. The tendency has been to rely on technological information from those supplying the technology. In many cases, the ability of the African countries to assess technologies is

prejudiced by tied aid and linkages between the suppliers of technology and those providing finance (either as grants, equity capital, or loans).

Technology assessment as a generic concept has now become part of the administrative language of many institutions in the industrialized nations and a few developing countries. The resurgence of the environmental agenda in the 1980s and the growth of analytical techniques for technology assessment has led to renewed emphasis on what is now called 'environmentally sound technology assessment' or 'ecotechnology assessment'. *Our Common Future* recognizes the dual nature of radical technological change: 'Technology will continue to change the social, cultural, and economic fabric of nations and the world community. With careful management, new and emerging technologies offer enormous opportunities for raising productivity and living standards, for improving health, and for conserving the natural resource base. Many will also bring new hazards, requiring an improved capacity for risk management.'¹⁵

The first reason for technology assessment is to provide a basis for long-term development policy. A second reason lies in the complexity of modern socio-economic systems. So rapid and unpredictable are the structural shifts, that merely stressing economic policy may be misleading. Much of the modern theoretical literature concentrates on the details of static assumptions about costs and prices, and tends to ignore dynamic aspects of ecological change, innovation, development, and linkages in the wider socio-cultural setting. Here, technology assessment is beginning to play a more important role.

The idea of technology assessment was first put forward in the United States in the late 1960s. It resulted from a growing awareness of the adverse effects of technological development and was 'devised to guide and control the development of new, large-scale, complex and extremely expensive technology in conformity with social goals'.¹⁶ The focus then was based on the view that technological change was the main source of ecological problems.

The case for the transfer and acquisition of environmentally sound technology has thus become a major theme in international relations, as illustrated by the case of negotiations over the conventions on climatic change and biological diversity as well as *Agenda 21*. Given the difficulties of assessing the ability of the developing countries to utilize the available technologies, it is necessary to set up mechanisms at the international and national levels to undertake technology assessment with a focus on environmental criteria.

Incremental Technical Innovation

Much of the discussion on technology transfer has focused on the importation of new technologies. This has led to arguments that place excessive emphasis on issues such as

intellectual-property protection and finances. While we recognize the importance of these issues, it is vital to stress the value of incremental technological innovations, especially at firm level. Studies on industry in the newly industrialized countries show clearly that much of what constitutes industrial dynamism is a result of the cumulative technological innovations introduced at the firm level. Such innovations are critical in the field of energy conservation, where retrofitting and adjustments in energy use are important and can have more immediate savings than the installation of new equipment. The variations in the intensity of energy use indicates where possibilities for incremental technical innovations to improve energy efficiency may lie. Over the 1970-90 period, energy intensity (or energy use per unit of GDP) has declined by 29 per cent in the industrialized countries, while it rose by 30 per cent in the developing countries.

Such innovations need to be distinguished from 'radical' or 'major' innovations which are often associated with the introduction of new capital goods. Incremental technical innovations are introduced during the regular operations of plants and their cumulative effect over time may be more important than introducing new equipment. The innovations could play an important role, not only in improving energy efficiency, but also in redesigning plants so that they use alternative raw materials or reduce emissions of harmful gases. Incremental technical innovations are often associated with capacity-building at firm level and emerge from training programmes as well as organizational change. On the whole, incremental technical change results from conscious policy efforts to enhance the capacity of workers, to improve their performance as well as the efficiency and output of equipment.

Environmentally Sound Technologies *International Considerations*

The role of technology in environmental management has been gaining in currency over the last two decades.¹⁷ Such recognition is also reflected in international conventions such as the 1979 Long Range Transboundary Air Pollution Convention dealing with acid precipitation in Europe, the 1987 Montreal Protocol on substances that deplete the ozone layer (especially the 1990 London Amendment to the Protocol), the 1989 Basel Convention on the transboundary movements of hazardous wastes and their disposal, and more recently the 1992 Framework Convention on Climate Change as well as the Convention on Biological Diversity. Technological-change concerns have now become a standard feature in international environment agreements.

Chapter 34 of *Agenda 21* sees environmentally sound technologies in the context of pollution as process and

product technologies 'that generate low or no waste, for the prevention of pollution. They also cover "end of the pipe" technologies for treatment of pollution after it has been generated.' They

are not just individual technologies, but total systems which include know-how, procedures, goods and services, and equipment as well as organizational and managerial procedures. This implies that when discussing transfer of technologies, the human resource development and local capacity-building aspects of technology choices, including gender-relevant aspects, should also be addressed. Environmentally sound technologies should be compatible with nationally determined socio-economic, cultural, and environmental priorities.

Environmentally sound technologies could fall into three main functional categories. The first would include processes and materials which are developed for neutralizing or reducing the harmful effects of a given operation on the environment without necessarily introducing fundamental changes in the original process. The second category covers process modifications including the use of novel monitoring and control techniques, and changes in the raw or intermediate materials, which may be incorporated into existing technologies to eliminate or reduce their negative environmental impacts. The third category includes novel and traditional technologies which are inherently sound from the environmental point of view.

Technology is the link between people and the resource base. The use of environmentally sound technologies, therefore, implies a new evaluation of this relationship by reassessing the methods used for the transformation of natural resources into useful products. From the 1970s there has been a marked response from industry. New technologies and processes designed to reduce pollution and other environmental impacts have been developed.

Advances in biotechnology, sound energy technologies, and alternatives to chlorofluorocarbons (CFCs) are notable examples of the response. However, these technologies are largely available in the industrialized countries which have the capacity to invest in their production, the institutional means to utilize them effectively, and the means to monitor and mitigate environmental damage. In addition, these countries have long-standing traditions in formulating policies that promote the application of new technologies in the economy. It is through the existence of such policies and the enabling programmes that the countries are able to put new products on the markets at a fast rate. It should be noted that these policies are aimed at promoting private-sector initiatives, and not to bring all new activities under governmental agencies.

The level of technological development in the African countries is low; they are consequently more prone to technological dependence. The low rate of technological change may imply a sluggish transition towards the use of

environmentally sound technologies. Further problems are created by the declining import capacity which began during the 1980s due to economic crisis. The decline of foreign direct investment during the same period has also weakened the ability of African countries to acquire imported technologies.

Environmentally Sound Technology Development and Transfer

Since environmentally sound technologies are an integral part of policies for sustainable development and the dimension of environmental issues is global, there is need for concerted action by nations. The international community is faced with the challenge of developing legal and trading regimes which promote the transfer of environmentally sound technologies to the developing countries.

The categories of transferable technologies include capital goods, services, and design specifications; skills and knowledge for production; knowledge and expertise for generating and managing technical change. Technology transfer is not only the introduction of technology, but also involves the imparting of the necessary knowledge and skills for the continual management of such technology. It is a two-pronged process, and for it to be effective a strategy aimed at dealing simultaneously on inflows of foreign technology and on the development of local technological capacity is imperative. The process starts with developing the capacity to make appropriate choices based on technology assessment. Apart from financial constraints, international trade regulations, patent laws, and licensing regulations have been identified as some of the barriers to the transfer of environmentally sound technologies. However, it has been argued that 'relaxation of intellectual property and licensing restrictions will not necessarily lead to greater technology transfer. The failure of developing countries to use fully technological information in the public domain e.g. patents that expired illustrates the problem. The ability to assimilate technology—not barriers to transfer—is the primary impediment to technological development in developing countries.'¹⁸ The ability to assimilate technology can be enhanced by capacity building which embraces 'the development of individual, group and institutional capacity of self-sustained learning, generation of technology and implementation of developmental or scientific activities of a defined range of problems'.¹⁹ This definition implies that the ability to assimilate technology is not only dynamic, but also cumulative. It is in this respect that those countries with some basic capacity in certain technological fields are able to achieve faster rates of technological assimilation than those which do not have any technological foundation in those fields.

The concept of endogenous capacity in science and tech-

nology has been described as the decisive prerequisite in the management of technological change towards sustainable development. The potential of environmentally sound technologies is said to be limited in effectiveness unless that capacity is built. The primary functions of endogenous capability are enabling the efficient use of imported technology and the creation of technology with appropriate characteristics. Capacity therefore encompasses the ability to: (a) make informed judgements on science-and-technology matters; (b) select and utilize technologies; (c) adapt and generate technologies; and (d) create new technologies. The prevailing policy environment and incentive regimes play an important role in technological capacity-building and utilization.

Technology and Climate-Change Abatement: An Example

The burning of fossil fuels, loss of forests through logging, and agricultural development coupled with rapid population growth increase the anthropogenic emissions of greenhouse gases into the atmosphere. Carbon dioxide (CO₂) and other gases, including methane and CFCs, play a major role in the 'greenhouse effect'. Nearly 56 per cent of these emissions come from energy generation through the burning of fossil fuels, about 21 per cent from agricultural activities (paddies and cattle breeding), and nearly 15 per cent from CFCs. The concentration of CO₂ in the atmosphere is also influenced by water pollution and deforestation which causes a decrease in the natural cycle of CO₂ absorption.

Nations have at least two options: the first option is to take preventive measures now in order to slow down the rate of greenhouse warming; the second is to undertake adaptive measures later to reduce the impacts of climate change. Since predictions on the magnitude of impacts are not specific, it makes sense to apply the precautionary principle and adopt the first option. This approach is reflected in the Framework Convention on Climate Change which recognizes the need for countries to take immediate action as a first step towards comprehensive strategies on climate change.

Article 2 states the objectives of the Framework Convention on Climate Change as stabilization of greenhouse-gas concentrations in the atmosphere at a level that would prevent dangerous anthropogenic interference with the climate system. Such a level should be achieved within a time-frame sufficient to allow ecosystems to adapt naturally to climate change, to ensure that food production is not threatened, and to enable economic development to proceed in a sustainable manner.

Advances in technology show that climate-change abatement can be realized by the use of environmentally sound technologies. The technical potential to cut emissions of greenhouse gases especially in the energy sector is

significant. By using existing cost-effective technology, global emissions could be cut by 20 per cent by the year 2020. Such technologies can be used to increase the efficiency of energy production and use; to switch from carbon to hydrogen-based fuels; to use carbon-free energy sources; to reduce CFC emissions; and generally to reduce deforestation (which will in turn lead to expansion of carbon sinks). The role of technology in climate-change abatement is stressed in Article 4(c) of the Framework Convention on Climate Change whereby parties undertake to 'promote and cooperate in the development, application and diffusion, including transfer of technologies, practices and processes that control, reduce or prevent anthropogenic emissions of greenhouse gases not controlled by the Montreal Protocol in all relevant sectors, including the energy, transport, industry, agriculture forestry and waste management sectors'. Article 4(e) strongly emphasizes the importance of technology in climate-change abatement and urges the developed countries to

take all practicable steps to promote, facilitate and finance, as appropriate, the transfer of, or access to, environmentally sound technologies and know-how to other Parties, particularly developing country Parties, to enable them to implement the provisions of the Convention. In this process, the developed country Parties shall support the development and enhancement of endogenous capacities and technologies of developing country Parties. Other Parties and organizations in a position to do so may assist in facilitating the transfer of such technologies.

The success of any programmes aimed at strengthening the technological capacity of the developing countries will depend to a large measure on existing policies and incentive systems for technological development in particular, and on innovation in general. There is already evidence that some of the economically dynamic Asian countries have made entrepreneurial responses to the Montreal Protocol and are exporting products that reduce CFCs.

Technology Policy and Incentive Systems

Technology Policy and Sustainable Development

Developing countries have generally relied on the exports of primary goods and labour-intensive manufactures based on natural-resource endowment and availability of labour. It is now accepted that these countries need to enhance growth; they need to increase exports with higher technology value added by diversifying their products and markets. To achieve this, the technological base of the production structure needs to be strengthened. A sound technological base is indispensable in expanding the productive capabilities of developing countries. Further, technological innovations offer them opportunities to fulfil their obligations in the search for sustainable development.

Institutional and government policy can hamper or accelerate

efforts to acquire and diffuse technologies. There is a need for government-adopted policies to induce rapid improvement in this area in view of the role of technology in development. The role of national technology policies should be to ensure that the objectives of sustainable development and environmental protection are given special attention. To be effective, such policies must be made comprehensive by addressing all functional sectors in society. They must also take into account socio-economic and cultural factors. National commitment to the objectives of such a policy is a necessary prerequisite.

Further, ideal science-and-technology policies are those which affect technological development directly by stimulating R&D, setting up a scientific infrastructure and giving preference to the output of indigenous technology. Regulation of access to foreign technologies is also important. Specific policy measures may include, first, a larger allocation of national resources to R&D institutions. This can be fortified by other financial incentives for R&D activities. Secondly, they should entail the establishment of a suitable infrastructure to cater for important matters such as training, joint research programmes, information availability and exchange, and appropriate legal machinery for enforcement. Thirdly, the encouragement of the acquisition and diffusion of environmentally sound technologies which are appropriate to local conditions and resources should be a key aspect of national technology policy.

Over the last three decades there has been a marked decline in returns from the export of raw materials, of which biological resources constitute a major part. Increases in production-and-utilization efficiency have continued to undermine the market for raw materials. Biotechnology itself is threatening a wide range of raw materials from the developing countries. Some of these countries have placed emphasis on downstream processing as a way of adding value to their exports.

Such programmes have led to extensive importation of machinery and contributed to local industrial production and employment. Very few countries, however, have placed the local processing of raw materials in the broader context of technological innovation. Where plants have been installed, they have added little to the national technological capacity. It was often assumed that the mere installation of machinery would lead to the accumulation of technological competence. Indeed, much of the technological development in African countries has been associated with the acquisition of equipment and machinery for the extraction of raw materials.

Although the policy instruments applied in various countries to promote technological innovation may look alike, it is important to recognize the underlying differences, especially in conceptions about international trade which is closely related to prospecting. The wide array of policy instruments used to promote technological innovation have received

little attention in most developing countries.

In the Western world technology policy has often been conceived in the context of causal relationships. This is evidenced by the US approach whereby focus is placed on basic science, health, energy, agriculture, and defence. The strategy adopted by Japan and the newly industrializing

Table 1. Government innovation policy measures

| Measure | Examples |
|--------------------------|--|
| Procurement | Central and local-government purchases and contracts, public corporations, R&D contracts, prototype purchases, setting of design and performance criteria, choice of priority technologies. |
| International trade | Trade agreements, technology-acquisition agreements, tariffs, foreign-exchange regulations, export compensation, import subsidies, licensing, infant industry protection, negotiation. |
| Public enterprise | Innovation by publicly owned industries, setting up of new industries, pioneering use of new techniques by public corporations, participating in private enterprises. |
| Scientific and technical | Research laboratories, support of research associations, learned societies, professional and technical associations, research grants, setting up science parks. |
| Education | General education, universities, technical education, retraining, vocational education. |
| Information | Information networks and centres, libraries, advisory and consultancy services, databases, technology monitoring, liaison services, public awareness. |
| Financial | Grants, loans, subsidies, financial sharing arrangements, venture capital, provision of equipment, buildings or services, loan guarantees, tariff remissions, export credits. |
| Taxation | Company, personal, indirect, and payroll taxation, tax allowances, depreciation allowances, tax exemption for private foundations. |
| Legal and regulatory | Patents, utility models, plant-breeders' rights, environmental and health regulations, contractual arrangements, conventions, inspectorates, monopoly regulations. |
| Political | Planning, regional policies, honours or awards for innovation, encouragement of mergers or consortia, public consultation, creation of new institutions, setting up of research funds, initiating legal reforms. |
| Public services | Purchases, maintenance, supervision, and innovation in health service, public building, construction, transport, telecommunications, infrastructure; administrative guidance. |
| External assistance | External aid, technical assistance, training, information provision. |
| International relations | Sales organizations, trade and diplomatic missions (science attachés), technical co-operation, research representatives, international negotiations. |

Source: African Centre for Technology Studies, Nairobi.

countries (NICs) of the Pacific Rim, on the other hand, has tended to take a systems approach, with a strong bias for industrial R&D. In the latter category of states research and commercial activities are closely focused on local and regional markets. These are important considerations when examining the transferability and relevance of some of these policy measures.

National policies on technology have often been influenced by differences in scientific and technological capability, industrial potential, as well as political and economic ideology. Technology-policy measures started receiving increased emphasis in the industrialized market-economy countries in the 1960s. This followed the recognition that science and technology had played a key role in the growth of the US economy over the previous fifty years. It was felt at the time, in the spirit of the Keynesian tradition, that government intervention was necessary to facilitate the role of science and technology in sustainable development.

It was also felt at the time that market and institutional imperfections affected the rate and direction of investment in R&D, and that government intervention was necessary. Researchers showed that firms were failing to make full use of their own research results. This feature mainly arises in circumstances where scientific knowledge is not properly integrated into the operations of the organization, probably due to a failure to embody the research findings into applicable technology.

In addition, risk, uncertainty, and the high costs of R&D investment reduced the rate of investment in R&D. This situation, it was argued, would reduce the social benefits of R&D and shift research towards short-term goals. Policy intervention was therefore required to maximize the social gains of R&D.

There are at least four broad technology-policy approaches adopted by the industrialized countries. A number of these have integrated technology policy into broad national-development strategies. Such countries include Japan, France, and Italy. In countries such as Germany, Denmark, and the Netherlands, technology policy is one of those policy instruments aimed at creating a suitable environment for economic change and international competitiveness. Technology policies in these countries are not formulated in the context of national plans.

This, however, may change as countries such as the Netherlands start to review the role of science and technology in sustainable development. In these countries technology policy is used to shape the direction of economic change. They have set up a wide range of consultative and co-ordinating procedures as well as institutions within government and industry. In addition, other institutional measures have been introduced to facilitate the linkages between industry and government. What remains conspicuously

lacking, however, is the issue of making the industrial policies sensitive to the ecosystem.

The Japanese model is the first category. The role of the Ministry of International Trade and Industry (MITI) in Japan has been a major subject of study.²⁰ What is significant is that MITI was conceived as an instrument for promoting technological innovation as a tool for international competitiveness, and not simply to promote trade in the context of comparative advantage. The approach has been systemic from the beginning. The people who shaped MITI had no sympathy for conventional economic theory. Their aim was to promote the most advanced technologies with the widest possible world market.

The United States has also introduced a wide range of measures aimed at enhancing its international competitiveness. Policy measures in the past have been selective, although government funding for new technologies has been a long-standing practice.

The second category includes a set of measures that allow the government to procure technologies at the early stages of their development. This approach was extensively used in the development of the electronics industry. In the United States for example, public procurement has been used to stimulate military technology. Other countries, especially in Europe, used public procurement to promote innovation in renewable-energy technology in the 1980s.

The third category of technology policy measures covers financial support for innovation. Tax credits have been used in countries such as Japan, Canada, and the United States to stimulate and promote innovation. Other well-established measures, such as grants, risk-sharing investment, and loans are used in most industrialized countries. In addition, new financial support schemes are currently being introduced in the industrialized countries to support small and medium-size firms.

These three major categories are currently being supplemented by measures which focus on specific sectors and are implemented through international collaborative programmes. The European Research Co-ordination Agency (EUREKA), launched in 1985, was designed to bring together industry, university, and government researchers in market-oriented information technologies in a bid to compete against the United States and Japan. Other collaborative research measures include the Programme for Basic Research in Industrial Technologies for Europe (BRITE) and the European Strategic Programme of Research and Development in Information Technologies (ESPRIT). In 1985 the EEC Council of Ministers approved a plan for a European Technological Community.

Unlike their industrial counterparts, the developing countries' technology policies have emphasized technology acquisition. These states have tied the transfer and acquisition

of technology to negotiations regarding exploration of and access to biodiversity. A few developing countries, however, have introduced fiscal incentives and financial assistance. Countries such as South Korea, Singapore, Malaysia, Mexico, and Peru have tax incentives. Financial assistance, however, is more widespread in the developing countries. Singapore, for example, has experimented with a number of R&D and product-development schemes in the last ten years. Most developing countries are yet to come up with effective policies for technological development. Where such policies exist, their administration and management have been poor.

Policy and Incentives in Africa: Policy Environment

Given the current state of the African countries there is a need to identify a few systemic technology-policy measures which can be used to stimulate and promote the sustainable development of indigenous technological capability. Such measures are defined as policy interventions which have the capacity to achieve systemic gains by reorganizing the economic system as well as the institutional terrain with minimal investment, administrative requirements, staff, and infrastructure. The main factors behind any approach are information flow, technical content, and institutional networking. The approach differs from other policy-formulation strategies in the sense that it utilizes the synergistic links between sectors. It is a systems approach instead of relying on linear causal relationships.

Technology-policy formulation is closely linked to prevalent trends in international trade and the related institutional arrangements. The current emphasis on technology as a tool for international competitiveness makes it increasingly difficult for most African countries to acquire emerging technologies. Although some of the experiences of other countries may be relevant for Africa, it is important to place these in the context of emerging design trends and institutional arrangements relating to access to technology and the related information. Technology-policy formulation has in the past been characterized by the enactment or publication of distinct laws or policy papers. The situation is changing and technology-policy formulation is becoming a dynamic process which is guided by continuous review, analysis, and research conducted by a wide range of institutions. The process requires continuous research and monitoring of both internal and international trends in innovation.

It has been stressed that achieving sustainable development will require major policy changes in the African countries. Such statements are often not backed by an appeal for studies which indicate the kinds of changes that need to be introduced. The tendency has been for the industrialized countries to suggest the extension of their policy measures to the African countries. This has often been possible because the discipline

of policy research is still nascent in developing countries and virtually absent in Africa. Pronouncements of a few people who are familiar with the policy needs for specific changes have often been confused with policy research, which is a discipline in its own right. This problem is compounded by the fact that scientists have often believed that they should speak to power directly and that their research results form the rational basis for policy-making. This view, however, ignores the fact that interaction between decision-making and reality is not always rational and depends on a wide range of factors which are the subject-matter for policy analysts. The area of policy research offers new possibilities for partnership between the industrialized countries and the African countries. These partnerships will essentially be research-oriented, although they will also take on the role of information dissemination. The partnerships that are developed for research and information-sharing will also serve the purposes of policy research.

One of the most important aspects of long-term social transformation is the rise of and retention of institutions. Institution-building and reform is a good indicator of the rate at which any society is changing. The success or failure of facilitating sustainable development in Africa will depend to a large extent on the ability of existing institutions to implement an agenda for change. So far, the view of African institutions by donor agencies has been limited to state institutions. While it is important to strengthen state institutions, it is necessary to broaden the scope of support to other institutions.

In the past, institution-building has been associated with providing infrastructure, finance, and training. These three have often been treated separately and donors have tended to emphasize one at a time. It has become obvious in recent years that the provision of infrastructure and funding to institutions does not necessarily lead to an increased capability to deal with development problems. In many cases the funding has either been wasted or misused. There is therefore a need to rethink the nature of institution-building relevant for the African situation.

Institutions are arrangements through which people manage change. This implies that institutions are essentially about people. The ability of the people to manage change will depend largely on the level of their competence. Alternative ways of supporting institution-building in Africa should therefore be based on competence-enhancement. This view, which departs from the narrow approach of providing funds and infrastructure, opens up a wide range of opportunities for designing new partnerships in institution-building. It also widens the range of institutions that can be involved in the process.

So far, training programmes have been too restrictive and often designed in the context of academic specification. There may be a need to rethink the orientation of the academic

Table 2. Government science and technology policy institutions in Africa, 1973–1986

| | 1973 | 1979 | | After 1979 | Total 1986 |
|---|------|----------|-------|------------|------------|
| | | Increase | Total | | |
| Ministry of Science or Ministerial Science Policy Council | 5 | +4 | 9 | +18* | 27 |
| Science planning body in general | 12 | +16 | 18 | +2 | 20 |
| Multisector body for co-ordinating scientific research | 18 | +6 | 24 | +4 | 28 |
| Natural science research | 2 | +14* | 16 | +9 | 25 |
| Agricultural research | 15 | +15* | 30 | +2 | 32 |
| Medical research | 6 | +14 | 20 | +1 | 21 |
| Nuclear research | 3 | +1 | 4 | — | 4 |
| Industrial research | 7 | +15* | 22 | +3 | 25 |
| Environmental research | 2 | +13 | 15 | 1 | 16 |
| TOTAL | 70 | | 158 | | |
| INCREASE | | 88 | | 40 | |
| GRAND TOTAL | | | 158 | 40 | 198 |

Note: * Indicates bodies with rapid increase.

Source: J. Forje (1987), *Trends in the Development of Science and Technology in Africa since CASTAFRICA I* (UNESCO, Paris).

specifications so as to provide a suitable environment for developing competence in environmental management. The conventional view has been to think of training in the context of where it takes place. As a result, the criteria for training programmes tends to restrict the choice of either local or foreign institutions. While it is important to build competence in specific African countries or regions, it is also important to create conditions under which training can be used as a means of transferring competence from the industrialized countries to Africa.

Africa is marked by a wide range of institutional arrangements aimed at formulating science-and-technology policies. These arrangements include ministries or ministerial committees, science planning bodies, multi-sector co-ordinating bodies, and scientific-research co-ordinating bodies. Some of these institutions have statutory authority while others do not. Over the years, science-and-technology policy-making has been moving from councils and committees to ministerial organs. Many of these institutions were established after the United Nations Conference on Science and Technology for Development (UNCSTD) held in 1979 in Vienna, which recommended that every country

should formulate a national science-and-technology policy. Table 2 shows the status of the evolution of these institutional arrangements in Africa.

Policy and Incentives in Africa: Incentive Schemes

In most African countries, incentives for technological development have often been implicit and mediated through investment incentives for industry. Where explicit incentives have been provided for technological development, they have often remained on the books or only articulated in policy documents.²¹ What so far emerges is that the main incentives for industrial development have favoured the importation of large-scale, capital-intensive investments with little consideration for technological development.²² In many cases the incentives explicitly provided for industry have tended implicitly to undermine the prospects for technological development.

For example, incentives provided in many countries to facilitate the installation of industrial plants have often worked against local technological development. These incentives often provide for lower import duties and tariffs on whole

plants and impose higher import duties and tariffs on raw materials that could be used to fabricate such equipment locally. The effect has often been that equipment that could be fabricated locally has been imported. Many African countries have the potential to manufacture most of the components necessary for assembling solar panels. But the high tariffs imposed on the necessary raw materials makes it easier for firms to import complete sets of panels. But because of the high labour costs in the industrialized countries, such products are usually expensive and only a few institutions and a small section of the population are therefore able to secure solar panels. Relaxation of tariffs would make it possible for cheaper solar-energy panels to be manufactured in some African countries.

In many cases tariff regulations are simply insensitive to the imperatives of technological development. For example, despite the growing importance of computer equipment in scientific research, many countries still place high tariffs on such equipment. Part of the problem lies in the misconception propagated in the 1970s that computerization was likely to displace jobs. Those countries which had strong job-creation policies imposed high tariffs on computer equipment.

Commercial organizations and individuals may not find it worthwhile to take into account environmental factors in the technologies which they develop or use. Entrepreneurs will be motivated by the existence of a suitable market before developing technologies. Incentives are therefore important, in that they create conditions which encourage involvement in a new area. Incentives cannot be established unless there is a clear government policy on technology and development.

After independence most African countries established tariffs and import-licensing systems to encourage investment in import-substitution industries. The industries depended heavily on imported machinery and inputs. Some of these countries also liberalized foreign-investment policies by taking measures to protect foreign investors against nationalization, reducing limitations on share ownership, increasing the field of activities and the size of profit remittances, and accepting arbitration as a means of settling disputes. These incentives proved useful in guiding activities of investors into areas which were deemed to be priorities. However, these incentives had their own limitations.

Experience has shown that the most effective and efficient inducements are those arising from financial stability, policy transparency, availability of skilled manpower, and large, growing domestic markets. More incentives are needed for those investments which encourage indigenous capacity-building. Incentives are also needed in areas that provide inputs which firms and individuals are unable or unwilling to provide themselves, or which help to reduce the risk of uncertainty associated with certain types of investment in the accumulation of knowledge and skills.

Manufacturers in most African countries receive no income-tax concessions, tariff reductions, or other incentives for their R&D efforts. Also, most research activities are not well co-ordinated, despite the establishment of national institutions for the purpose. Most intellectual-property laws in Africa do not encourage the use of knowledge which is already in the public domain. These laws are also deficient in that there is no room for appropriate technologies developed by indigenous people.

The barriers encountered by transnational corporations in the transfer of environmentally sound technologies include: (a) reduced expectations of profits from sales of such technologies due to lack of markets, complex legal requirements, and lack of market information; (b) lack of adequate technical and social infrastructure; and (c) unfair competition due to lack of environmental regulations and standards in developing countries. During the 1980s many developing countries relaxed regulations governing technology and foreign investment in their countries. Policy changes easing controls over patents, licensing, and trade-marks were introduced. These efforts were a recognition of the importance of technology and also the importance of international collaboration in this area. However, more *direct incentives* need to be provided to support technological development in general, and environmentally sound technologies in particular.

Conclusion

In the light of the above assessment, it appears that the success of international co-operation programmes will depend largely on the extent to which governments in the developing countries introduce reforms at the national level to facilitate the adoption and development of environmentally sound technologies. The issue here is not simply the introduction of minor reforms to accommodate certain types of 'clean technologies'. The challenge involves integrating environment and development at the policy, planning, and management levels as outlined in chapter 8 of *Agenda 21*. As that chapter stresses, the shift towards environmentally sound development may require an 'adjustment or even a fundamental reshaping of decision-making, in the light of the country-specific conditions . . . if environment and development is to be put at the centre of economic and political decision-making'. Doing this alone will require international co-operation in managing economic-policy reforms which take into account the imperatives of sustainable development. Without such reforms, the call for international co-operation in the transfer of environmentally sound technologies to the developing countries will not amount to much.

Indeed, those countries that introduce incentives which

promote the development of environmentally sound technologies will strengthen existing local technological efforts, which in turn will put them in a better position to benefit from international co-operation. In this regard, the prospects for the transfer of technology in the context of the Convention on Biological Diversity or the Framework Convention on Climate Change are limited for most countries, except those that put in place effective national technology-policy measures to promote the development of relevant technologies. The success of international co-operation arrangements, therefore, depends to a large extent on what countries do to promote local technological initiatives.

Notes and References

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1. World Commission on Environment and Development (WCED) (1987), *Our Common Future* (Oxford University Press, Oxford), 4.
2. This, however, should take into account the risks associated with urbanization and population migration.
3. This is exemplified by the endorsement of the International Chamber of Commerce's Business Charter for Sustainable Development (BCSD) by over 600 private corporations. The adoption of such a code of behaviour, if extended to their subcontractors, could significantly contribute to the promotion of sustainable development.
4. For a detailed collection of case studies on this theme, see S. Schmidheiny (1992), *Changing Course: A Global Business Perspective on Development and the Environment* (MIT Press, London).
5. The emerging trends suggest that for most developing countries, the most suitable starting point is the application of environmentally sound technology to small- and medium-scale enterprises, which are also the main sources of employment and also pose widespread environmental risks.
6. M. Brown (1992), 'Science, Technology and the Environment', *OECD Observer* (Feb./Mar.), 12.
7. While governments continued to formulate policies based on national competition, firms increased their degree of co-operation, especially in the field of technology transfer. For details of such arrangements, see Calestous Juma and Mark Sagoff (1992), 'Policies for Technology', in J. C. Dooge *et al.* (eds.), *An Agenda of Science for Environment and Development into the 21st Century*, (Cambridge University Press, Cambridge).
8. The establishment of Thailand's Environmental Research and Training Center with support from the Japanese government illustrates the point.
9. The challenge for the international community is therefore to identify ways of enhancing the capacity of the developing countries to utilize the emerging and available environmentally sound technologies.
10. Gro Harlem Brundtland (1991), *Environmental Challenges of the 1990's: Our Responsibility Towards Future Generations* (The Tanner Lecture on Human Values, Clarence Hall, Cambridge) (14 Feb.), 9.
11. UNCTAD (1990), *Transfer and Development of Technology in Developing Countries: A Compendium of Policy Issues* (New York).
12. J.-E. Aubert (1992), 'What Evolution for Science and Technology Policies?' *OECD Observer* (Feb./Mar.), 5.
13. R. Vernon (1989), *Technological Development: The Historical Experience*, Economic Development Institute Seminar Paper no. 39 (World Bank).
14. For a more detailed application of technology assessment to biotechnology, see Norman Clark and Calestous Juma (1991), *Biotechnology for Sustainable Development: Policy Options for Developing Countries* (Acts Press, African Centre for Technology Studies, Nairobi).
15. WCED, *Our Common Future*, 217.
16. Norman and Juma, *Biotechnology for Sustainable Development*, 28.
17. Calestous Juma and Jackton B. Ojwang (1992), *Technology Transfer and Sustainable Development* (Acts Press, African Centre for Technology Studies, Nairobi).
18. Juma and Sagoff, 'Policies for Technology', 272.
19. Daniel A. Bekoe and L. Prage (1992), 'Capacity Building', in J. C. Dooge *et al.* (eds.), *An Agenda of Science for Environment and Development into the 21st Century* (Cambridge University Press, Cambridge).
20. See e.g. C. Johnson (1982), *MIT and the Japanese Miracle: The Growth of Industrial Policy, 1925-1975*, (Stanford University Press, Stanford, Calif.).
21. See e.g. A. M. Goka *et al.* (1990), *Performance Review of Institutions for Technology Policy in Ghana, Nigeria and Tanzania*, IDRC Manuscript Report 241e, (International Development Research Centre, Ottawa, Canada).
22. 'The different types of incentives . . . can be categorized generally as special concessions made available under investment and tax codes, protection through trade and industrial licensing policies, credit and equity participation facilities through development finance corporations, and favourable interest rates. Provision of adequate infrastructure and services and creation of a stable environment were also seen as important means of attracting investment. Investment codes tended initially to be oriented toward large-scale foreign enterprises, with subsequent efforts to include domestic investors, especially in small-scale enterprises. The benefits generally depended heavily on the amount of capital invested or made capital available at low cost (both financial capital and imported capital goods). This had, however, the effect of biasing the structure of incentives in favor of large, capital-intensive investments.' W. F. Steel and J. W. Evans (1984), *Industrialization in Sub-Saharan Africa: Strategies and Performance*, World Bank Technical Paper no. 25. (World Bank).