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Mobilizing Technology for Developing Countries

Charles Weiss, Jr.

Summary. A new problem in technology policy—a discipline hitherto largely concerned with the modern industrial sector—is posed by the need for technology suited to creating productive jobs and providing minimum public services at a cost and level of sophistication within the reach of poor people in developing countries. Careful consideration must be given to overall and sectoral development objectives, economic and manpower resources, and the local institutional and sociocultural context. This may indicate the need for both hardware innovation, such as low-cost alternatives to waterborne sewerage, and social ("software") innovation, such as training large numbers of supervisors to implement improved technologies for labor-intensive civil works.

The 15 years since the United Nations Conference on Science, Technology, and Development in Geneva have taught us that what seemed at first to be technological obstacles to development frequently turn out on closer examination to have been policy failures.

If economic policies prevent competition, firms will pass up opportunities for the use of known technology to improve quality. If financial authorities overvalue local currency, firms will have an incentive to import equipment and raw materials in place of locally available supplies and will neglect local sources of technology. If government marketing boards pay too little for higher quality, processors of agricultural commodities will neglect their machines and will fail to take advantage of improved technology. If banks are unwilling to extend credit to small farmers, the latter will continue to face severely restricted technological options.

If governments do not give high priority to the provision of safe water to poor people at a cost the country can afford, the agency charged with this responsibility will neither attract good managers, provide proper working conditions for its engineering staff, nor adopt appropriate design criteria, and hence will fail to employ the most suitable technology (*1*).

In each of these situations, the fact that a technology that seems suited to a local situation is, in fact, not used is a symptom of a deeper problem. In the language of experimental science, technology is a probe that reveals issues that might otherwise have escaped attention. But this does not mean that the problems thus revealed can necessarily be alleviated by the introduction of the "missing" technique. On the contrary, evidence is piling up that the impact of the introduction of any particular piece of equipment—whether tractors in southern Asia (*2*) or waterless toilets in Vietnam (*3*)—depends heavily on the social and institutional structures on which it is superimposed.

For this reason, there are many situations in which an intervention focused purely on technology—whether indigenous or foreign and whether new, adapted, or transferred—is likely to be doomed from the start. In such cases, the introduction of hardware must be accompanied by and integrated with a package of policy and institutional changes if a desired innovation is to be effected, so it is more illuminating to refer to the institutional change necessary to the solution of a social problem as the "software" of the technology.

An example may make this point clearer. One may imagine three approaches to the problem of providing water to small farmers from aquifers near the surface: (i) designing and testing a small hand- or pedal-powered pump to be used by one or two farmers and encouraging a system to market and maintain such pumps; (ii) encouraging the installation of diesel-powered tube wells serving 50 or so farmers and ensuring an equitable distribution of the water through cooperatives; and (iii) encouraging entrepreneurs to hire out truck-mounted pumping equipment by the hour to individual farmers.

Each of these overall approaches—hardware plus institutional support—constitutes an alternative technology. The choice among them should depend on careful overall assessment of local technoeconomic, geographic, ecological, and social factors, as well as the desired balance between growth and equity. Such a technology assessment, a key element in the choice of "appropriate" (locally suitable) technology for particular investment projects, should be built into procedures for project preparation and appraisal in governments and development assistance agencies (*4*).

The crux of this approach is the focus on the problem rather than on the technology. "Technology is the answer—but what is the question?" (*5*). In the previous paragraphs, the objective is delivery of water, not development of pumps.

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New technologies may open our eyes to problems hitherto thought insoluble—but even then we must ask ourselves the critical question, "What are we trying to do?"

The earth resources satellites, for example, have provided vastly improved resources data for development planning in agriculture and forestry. They can also provide up-to-date maps in areas where base maps are as much as 30 years out of date. But to take full advantage of Landsat technology requires not only an appreciation of its potential but also a clear conception of overall objectives. Specifically, it requires a system oriented toward the needs of the user and tied closely to user organizations, as well as a substantial effort to educate, reorient, and often reorganize foresters, geologists, and regional planners toward the possibilities created by the new data. The data-gathering part of this system includes both Landsat and traditional methods of aerial photography and ground observation, and is often quite different from the "wishing list" of hardware-oriented researchers (*6, 7*).

In the same vein, the Satellite Instructional Television Experiment in India showed the value of television programs specifically designed for remote villages. The National Aeronautics and Space Administration made available the direct-broadcast ATS-6 satellite, and Indian scientists developed indigenous hardware rugged enough to be reliable under village conditions. But the programs developed for satellite broadcasting turned out to be useful in villages within range of urban transmitters as well—their value was independent of the means of delivery. Yet the worldwide effort to develop radio and television programming materials specially suited to remote areas falls far short of the need (*8*).

In developed countries, mechanisms exist to translate needs into technology—either through the demands of the marketplace or through government-sponsored basic and applied research, development, and demonstration. The system does not work perfectly, nor is it under perfect control. But the technological and institutional capability exists to make it work, even in difficult circumstances, given the will to define objectives and implement them.

Most developing countries, on the other hand, have limited capacity for local innovation in both the public and the private sector. Even their capacity to define objectives, select technology, adapt it to local needs, and implement, manage, and operate it is at a premium. Moreover, developing countries, except for a few oil exporters, do not command the market power to attract innovators in the private sector to work on their problems. It is, for example, vastly more profitable for drug companies to develop new palliatives for the real or imagined ills of the middle-aged rich than to develop effective cures for tropical diseases that kill or incapacitate hundreds of millions of poor people. Developing countries thus lack both the market power and the indigenous capacity to direct technology toward their problems.

Sectoral Outlook on Technology Policy and Appropriate Technology

Twenty years ago there were few who doubted that technological progress—then conceived as powered by advances in science and engineering in the developed countries—would lead to a better world. The world was then confident that the technology needed by developing countries was available to them, perhaps with minor modifications, in the developed countries and that the major problem of technology policy in developing countries was to master that technology and to overcome cultural and institutional obstacles to its rapid acceptance.

Today this automatic acceptance of technological change is questioned in both developed and developing countries—not because of any generalized loss of faith in technology, but because of greater understanding, born of experience, that the impact of a technology depends on the institutional, economic, social, and ecological situation into which it is introduced; and conversely, that government policies, market incentives, and institutional and social constraints may have as much influence on the evolution of technology as the activities of formal technological institutions.

This increased understanding of the impact of technology on developing countries has led policy-makers to recognize the need for a more appropriate technology—which has come to mean technology that is smaller in scale, more labor-intensive, more subject to local mastery, repair, and control, and more in ecological and cultural harmony with its surroundings than the technology that would likely be used in an analogous situation in the North—and to recognize that the obstacles to the development and use of such a technology are as much social and political as technological (*4, 9*).

This new demand for more appropriate technology is in part an aspect of a major revision in development thinking, away from a preoccupation with increasing the gross national product through the transfer of technology to developing countries and toward increased attention to agriculture and a direct concern with the welfare and the productivity of the poor (*10*).

Alternative paths of development based on a more appropriate technology can evolve only as the result of consistent and long-term application of a different development strategy and set of global incentives. It then becomes a critical goal of technology policy to design national policies and institutions so as to guide the evolution of the technology in use into appropriate directions and to ensure local mastery of that technology. This requires an intimate knowledge of the effects of market, social, and administrative forces on technology, and is a critical change in emphasis from the traditional concern of technology policy-makers with research programs, scientific infrastructure, and manpower development. It implies a close integration of technology policy with broad development policy. In the future, even the existence of development policy and technology policy as separate disciplines will be seen as an artifact of the historical patterns of training and socialization of development economists and technologists.

The need for more appropriate technology has implications for the traditional pattern of innovation. By and large, appropriate technologies do not yet exist as sound, well-tested hardware that can be located in engineering catalogs and plugged into development projects. The technology in use in developing countries has evolved in response to a set of incentives designed to promote investment based on imported technology. Ways must therefore be found to finance the "front-end" costs and risks of innovations intended to benefit the poor—costs and risks that in most technical fields are borne by wealthy civilian or military customers whose expenditures are governed by noneconomic motivations.

We are all aware of the suspicion in developing countries that the appropriate technology movement is an attempt by developed countries to fob off second-rate technologies they would not use themselves. This reaction is natural in the light of the history of relations between North and South. It will be dispelled as planners and technologists in developing countries confront the capital and other limitations that face any attempt to bring technology to bear on the needs of the poor, including creation of productive jobs on a massive scale, and devise strategies of their own to satisfy these needs within their resource limitations. We may also hope that the rise of alternative technology movements in developed countries will show that many people in rich countries have come to question the appropriateness of prevailing technology for their own needs.

"New" Technology Policy

The new emphasis on holistic technology assessment and on ensuring that technology benefits the poor places new demands on the relatively young discipline of technology policy, which, after all, is only now coming to understand the technological aspects of the "old" paradigm of development strategy, namely the role of domestic engineering capabilities, of the level and structure of tariff protection, of administrative regulation of technology importation, and of indigenous research and development in such industries as steel, petrochemicals, and mining (*11*). There is a critical need for a shift in emphasis among technology policy-thinkers away from the development of technological capacity in these "strategic" industries along the lines already developed in the industrialized countries, toward the development of technology and technological capacity appropriate for the needs of the small farmer, the small entrepreneur, and the urban and rural poor.

This shift, in turn, demands an attempt to achieve a holistic understanding of the present status and future development of a broadly defined element of the economy—urban shelter, say, or food crop production, storage, and marketing—so as to assess the present and likely future needs for and impacts of technology. Such an analysis demands a long time horizon, a willingness to disaggregate, and an attention to economic, technological, cultural, and sociological detail.

We are far from having such a methodology for relating technology to overall development needs. But just as development technologists are learning to consider economic factors, development economists are learning to take technological and other long-term factors into account. Economists often feel most comfortable with short-term projections of available data and policy recommendations whose effects will be immediate, whereas technologists tend to place their hopes on technologies whose impact will not be felt for 15 to 25 years. But this artificial gap in time horizon is being bridged. For example, the energy crisis has brought both economists and technologists to realize that policy, structural, and technological changes are all needed for an effective energy strategy, and that the time scales for these changes cover broad and overlapping ranges.

Development assistance agencies have evolved a sequence of country and sector studies that are intended, among other things, to help ensure that the projects they finance address the high-priority problems of the countries they seek to help. In general, economic studies of countries review the salient facts regarding the overall state of a national economy, while sector studies examine broad issues concerning a particular area, such as agriculture, industry, transport, population, nutrition, or urbanization.

Country and sector studies are intended to provide essential background on strategic policies and issues that critically influence the suitability and impact of technology. This background is essential for the kind of technology policy I outlined in the earlier paragraphs. For this reason, while these studies are not now conceived as exercises in technology policy, the approaches they use may help to bridge the gap that now exists between development policy and technology policy.

I illustrate this point with reports from the World Bank, which is the largest multilateral development assistance agency in the world. Because many developing countries have used tariffs to nurture inefficient industries in the name of import substitution, country studies by the World Bank commonly call for a shift to a liberal trade policy and the promotion of exports. This recommendation should immediately call the attention of the technology policy-maker to the need to strengthen the local capacity for overseas market intelligence, export standards, quality control, troubleshooting, preinvestment work, product development, engineering, development, and (lastly) research.

Another common focus of these country studies is problems of urban poverty. Such studies should have the effect of calling the attention of technological planners to the need for reorientation of part of the local technological community toward the development and design of low-cost hardware and buildings in close support of government or private efforts to provide the urban poor with basic services. Obversely, they should make the managers of public sector programs—for example, in housing, nutrition, and small-farmer agriculture—aware of the need to develop low-cost technologies appropriate to local conditions; to diffuse capital-saving, scaled-down industrial technology, especially to small firms; and to develop and subsidize the distribution of low-cost foods to remedy nutritional deficiencies among poor pregnant and lactating mothers and young children (*12*).

A typical World Bank sector study in agriculture gathers data on and analyzes a number of basic determinants of technology: the labor market, including patterns of migration; the organization of the system for marketing agricultural inputs and outputs, including processing, storage, and transportation; the land tenure system and distribution of farm size; the availability and cost of credit to farmers of different kinds; nonfarm employment; and rural income distribution. In addition, such a study may examine issues of overall strategy that are critical to efforts to improve technology, such as the proper balance between irrigated and rain-fed agriculture, between opening new lands for settlement and increasing crop yields on land already under cultivation, and between the development of different geographical regions.

All these considerations exert at least as much influence on the technological development of the agricultural sector as the more traditional concerns of technology policy-makers—so much so that they have been dubbed implicit technology policy (*13*) by the last decade of writers on technology policy.

It is a relatively small step, although one not always taken in practice, to such explicitly technological issues as the technology package available to farmers of different regions and sizes; the need for research and extension organizations; policies for mechanization and for exploitation of water resources; and the need for training and education of farmers, extension workers, credit officials, researchers, and government officials.

For example, a World Bank agricultural sector mission to northeast Brazil found that one of the main obstacles to the agricultural development of this vast, ecologically degraded region is the lack of a package of farm technology much superior to the traditional technology, which, although of meager productivity, was within the reach of the farmers and well suited to a region of frequent drought. This mission led to Bank financing of a $145 million project for the establishment of a network of agricultural research stations in northeast Brazil.

Buildings and road construction is another area where badly needed efforts to improve technology are severely constrained by the difficulties and incentives faced by the local industry. In developing as in developed countries, governments often use construction activity as a macroeconomic spigot by which to regulate aggregate economic activity. A contractor in a developing country must therefore organize his firm in such a way that he can retain a small cadre of capable and trusted managers during periods of recession, and expand rapidly to take advantage of a sudden spurt of contracts during flush times. This is not a pattern suited to the testing and adoption of technical innovations (*14*).

In many developing countries, lack of training and finance for local contractors and the weakness of the local building materials industry are major obstacles to the use of a more appropriate construction technology. These are combined, in one west African country, with a grossly overvalued local currency, which makes it profitable to import prefabricated building materials even though the country suffers from severe unemployment (*14*).

The sectoral overview can also help in the definition of technological requirements common to many developing countries, as may be seen from World Bank research on appropriate technology for civil works construction, sanitation, forestry, and rural transport.

The civil works study examined the feasibility of alternative civil construction technologies using different combinations of labor and equipment. It developed and demonstrated technologies that improve the productivity of labor and also create employment, through modifications in both hardware (handcarts, wheelbarrows, rail carts, ropeways, animal-drawn rollers) and software (worker incentive systems, site management practices, health and nutrition standards) (*15*).

The sanitation study sought to determine the technical and economic feasibility of various options for meeting the water supply and waste disposal needs of the urban and rural poor. Preliminary results indicate that there are many viable technological alternatives between the pit privy and a complete waterborne sewerage system (such as aqua privies, cartage systems, and septic tanks) and that environmental sanitation can be improved by the installation and maintenance of systems costing one-tenth to one-third (per household) as much as a conventional sewerage system (*4, 16*).

A global overview of the world forestry problem has focused attention on the role of wood in providing fuel and cash income to small farmers as part of a larger package of credit, inputs, and technology—a major shift in emphasis from traditional, industrially oriented, capital-intensive forest projects (*17*). In rural transport, a major need of remote villages is basic access to markets at low cost. It turns out that there already exist a large number of commercially available, rugged, low-cost vehicles suitable for off-road transport of goods (*18*). One way to provide basic access would be to operate such vehicles over low-cost tracks in order to transport goods to feeder roads accessible to trucks.

A somewhat different approach to the mobilization of technology for the benefit of developing countries is illustrated by the situation of cotton. About 125 million of the poorest people of the world depend on cotton for their livelihood, and 11 countries with a per capita income less than $200 depend on it for more than 10 percent of their exports. Cotton's share of world textile markets has dropped from 70 to 51 percent since 1955, largely because the newer synthetic fibers offer the consumer permanent-press and other special features.

Three development agencies have put forward an innovative proposal for an integrated global program to defend the market share of cotton. The program would consist of agricultural production research (to increase yield, improve quality, and lower production costs); industrial research (to give cotton desirable end-use properties such as permanent-press and make it more compatible with high-speed textile machinery); technical assistance to mills in developed and developing countries (to facilitate the transfer of newly developed cotton technologies); and marketing and promotion (to strengthen the image of cotton as a desirable fabric and to promote its new features).

The proposal calls for the establishment of an intergovernmental organization, to be called Cotton Development International (CDI), which would be funded in part by cotton-producing countries and in part by aid donors and would complement the efforts of existing organizations to assist cotton (*19*). The proposal is now before governments. The CDI proposal is patterned after the successful International Wool Secretariat and Malaysian Rubber Research Board, which have shown how modern technology can maintain the competitiveness of natural fibers against materials produced by large chemical firms and backed by modern integrated marketing and technology.

Long-term, technologically oriented sector analysis can provide background information for assessing the impact of an innovation and for guiding policies intended to lead to a system in which desirable technology will come into use. Developing countries need to develop the capability to carry out, or at least supervise, studies of this kind, and to revise them periodically in the light of experience.

At the same time, many historically important innovations have taken place, not because they fit in with prevailing economic, social, and political structures, but because they overcame them (often through the heroic efforts of an "innovation champion") or made them obsolete and forced vested interests of various kinds to accommodate a new and superior technology. These technologies emerge from the ideas of researchers and inventors who draw on their knowledge of the needs of the market and their understanding of technological possibility.

We are unlikely to identify such technologies by sector work. Moreover, policy analysts have in the past seriously misjudged the potential for technological innovation to change a situation or, as happened in the energy crisis, for unexpected events to create an immediate need for technological innovations.

The role of technological sector analysis, then, is not to control the direction of innovation, but to guide researchers and innovators toward socially important technological problems, to develop policy instruments that will lead to desirable innovations, and to develop the technological capacity to define and solve local problems and implement the solutions.

International Cooperation for Technological Innovation

What, then, are the lessons of the new, broader view of technology policy for those whose profession is the development of programs of international cooperation in technology and science?

At the project level, it seems to me that we have no choice but to concentrate our efforts on the areas that are most likely to bring practical results to pressing problems, and try to foresee and set in motion as much as we can of the total innovation process. This means that we must probe not only the technological merit of any proposal, but the probable technoeconomic feasibility of the technology once it is developed and implemented. We should compare the proposed technology, under realistic conditions in a developing country, with existing technology under comparable circumstances. As far as possible, we should consider the opportunity costs of inputs and the true value of outputs, correcting for distortions in market prices and for external factors such as social and environmental effects. We should also consider whether that technology is likely to be implemented on a practical scale if it has succeeded in the laboratory, or whether social, institutional, cultural, or political obstacles are almost certain to block it.

The question of whether a development assistance agency should help researchers and innovators to try to introduce innovation into a repressive or stagnant society raises difficult ethical questions. There is no point in undertaking a project if unchangeable social, institutional, or political obstacles are certain to block it. There are even times when such attempts are physically dangerous to the innovator.

As a practical matter, governments of developing countries usually control the introduction of innovations that run counter to their current development strategy. However, these governments are, with a few exceptions, not monoliths. For this reason, there will be times when a successful technological experiment can be the vanguard of social change. Development of small-scale energy sources may open up new possibilities for rural development in areas remote from power grids. Development of technologies for small-scale farming or industry may undermine the justification for exclusive reliance on large-scale technology. Research or demonstration projects may thus highlight the existence of alternative strategies as a first step toward mobilizing public opinion or readying official opinion for change.

In short, programs of technological innovation may be undertaken even if the innovation, if successful, would run athwart existing policies and institutions. Project planners should take the overall situation into account and design the project to maximize the probability of innovation on a significant scale. They should consider the likely obstacles to innovation and try to deal with them as early as possible, and they should establish contact with potential users of the technology as early as possible. This may pay extra dividends: once we have put ourselves in the shoes of the person who will have to commercialize or promote the innovation, even if the latter is still a gleam in a researcher's eye, we may uncover hidden bottlenecks to the innovation process or unsuspected allies, technical collaborators, or even sources of financial support.

This focus on the total innovation process has implications for the design of individual projects of international cooperation and for the design of international programs and institutions. For example, a number of subjects for potential collaboration between developed and developing countries are relatively straightforward explorations of an engineering-based technology that has not benefited much from recent technological advances, say the bicycle (*20*), the wood stove (*21*), or the microturbine (*22*).

The success or failure of such a project will probably depend at least as much on the skill of its promotors in commercializing the innovation as on its technoeconomic prospects in the laboratory. It is therefore reasonable to ask that the project promoters themselves have (or cooperate with someone who has) a clear understanding of the problems that will confront those who seek to commercialize the projected innovation and who will establish links with prospective manufacturers, in developed or developing countries.

In the case of a device that is to be exported by a developed country, this means discussions and perhaps tentative arrangements with the manufacturer, preferably together with partners in the developing country concerned. If it is to be manufactured in the formal sector of the developing country, provision must be made for collaboration with a manufacturer there so that the design of production prototypes will be consistent with his fabrication capability as well as with the conditions confronting the potential user. If the device is to be made in the informal sector—the village or urban workshop—arrangements should be sought with government or voluntary agencies to test and promulgate the designs and ensure that they are suited to local conditions.

The "not-invented-here" syndrome affects all human organizations, and time spent early in the project to develop these links will be repaid many times at a later date. This requirement can be relaxed somewhat if the engineering concept is sufficiently novel to require extensive testing, and still more if research is needed to extend fundamental understanding before a new technology can be devised.

The projected process of innovation may also be a key element in determining the balance and relationship between researchers in developed and developing countries who are collaborating in an undertaking. The sophistication of the required research and of the eventual production technology is an important consideration.

A less obvious but no less critical consideration is the extent to which a design is likely to be dependent on features specific to the developing country, such as raw materials, customs, traditions, and regulations. The appropriateness of a building technology, for example, depends not only on local clays, rocks, and living habits, but also on the structure and capabilities of the local construction industry and on the local economic and regulatory incentives and constraints within which it operates. For this reason, international programs of building and building materials research depend critically on having collaborators in the developing countries who know the local building industry and are capable of analyzing in detail the situation facing the building contractor (*14*).

Such collaborators need not be research institutes. There are advantages to seeking out collaborators with operating capabilities (ministries of housing or education, associations of building engineers, or, as in the case of an outstanding urban shelter project in El Salvador, private foundations concerned with community development), especially when implementation of the technology in question demands intimate knowledge of the local cultural and social situation (*23*). Participation in such programs will strengthen the technological capability of these operating organizations—a goal at least as important as that of strengthening the formal technological infrastructure.

The Appropriate Technology Movement

Many of the seminal ideas in small-scale, ecologically appropriate technology in developed and developing countries are due to small, informal groups who are working with minimal equipment and financial support and often with missionary zeal for a particular technology or pattern of life, which may be contrary to the ideas prevailing in their country (*24*).

These groups are the life of the appropriate technology movement. Yet they cannot by themselves provide tested alternatives to conventional technology on a scale commensurate with the scope of the problem they have helped to identify. There is a need to keep these groups alive and flourishing, even while their ideas are being translated into hardware and software that can be tested and applied on a large scale.

This creates a dilemma for those of us in "establishment" organizations who agree that it is essential to devise simpler, cheaper technologies for use in developing countries. It is far easier to set up international institutes to do this than it is to nourish the fragile grass roots institutions attempting, often against great odds, to identify local needs and to promote a piece of "appropriate" hardware or a new concept in community organization.

There is a need for modest international support for these institutions to provide links between them and the outside world and to help them tackle problems beyond their capacity (*25*). But it is essential that the international structure not swamp the fragile national institutions it is supposed to serve.

Need for Basic Research

Finally, let me turn from innovation to the other end of the scientific spectrum, namely basic research. It is commonly said that what developing countries need is not basic research, but practical research aimed at practical problems. I do not agree. Developing countries by and large do not overinvest in basic research; they underinvest in indigenous technology. If there is no local capacity to absorb technology and carry out local innovations, basic research becomes isolated from the needs of the country and is magnified in the public mind.

Yet basic research on a modest scale is a good investment for developing countries. It is a relatively inexpensive way to keep good university faculty in the country who are in touch with world trends in technology, intellectually alive, and turning out well-trained students (*26*).

Ideally, basic research in developing countries should be organized around a local problem that is both scientifically challenging and of major importance—parasitology, for example, or wildlife ecology. But considering the value of basic researchers in developing countries, this should not be an absolute requirement. And considering that they often have a difficult time finding long-term support at even minimal levels, their colleagues in developed countries should do their best to sustain them through international scientific collaboration, national funding bodies (which are generally responsive to the wishes of the domestic scientific community), and international bodies such as the International Foundation for Science.

There is no question that there is a need for basic research of the highest quality on scientific problems of importance to developing countries. Tropical meteorology (*27*), parasitic disease (*28*), insect endocrinology (*29*), nitrogen fixation (*30*), and the properties of unstudied species of tropical flora and fauna (including many that have nourished millions of people for generations) (*31*) are only a few of these problems that are worthy of the attention of the best scientific minds anywhere in the world.

In most Western countries, the evolution of basic science is by tradition autonomously regulated. Nevertheless, the emphasis in basic research is determined in large part by its economic importance to the developed countries. We know little about many scientific problems that are important to developing countries, not because they lack intrinsic interest but because they are not thought to be critical by national funding agencies in developed countries and do not arise from the usual experience of scientists in developed countries. Insights into these problems may arise as a by-product of progress in related scientific disciplines, but advances are slow compared to those in more fashionable areas.

In fortunate instances, economic motivations may turn the attention of developed countries to the needs of the developing countries. Diarrheal diseases, for example, are a leading cause of death among poor children in developing countries. They are also a major source of economic loss to the tourist industry and to multinational companies who must post employees and their families to locations for which they are immunologically ill-prepared. Recent advances in the microbiology of the human intestine—an unsung research area of immense human importance—raise hopes that better understanding of the causes of diarrhea may lead to practical benefits to tourists, international businessmen, and poor children alike (*32*).

In a very different area of basic science, developed countries, through the Global Atmospheric Research Program (GARP) of the World Meteorological Organization and the International Council of Scientific Unions, are spending hundreds of million of dollars to study the fundamental physical properties of the tropical atmosphere. This program is primarily designed to acquire the scientific basis for global climatic models that will make possible long-range (10- to 30-day) prediction of the weather in temperate regions.

As it happens, these models are also essential for even short-range (1- to 3-day) predictions of the weather in tropical areas, as well as predictions of the strength and timing of the monsoons in different parts of the tropical world. Thus GARP promises major scientific advances directed to the needs of developing countries. It also provides an opportunity for meteorologists from developing countries to collaborate with the best of their colleagues in the world on a problem of great importance to both developed and developing countries (*27*).

Concluding Observations

The impetus behind the 1979 United Nations Conference on Science and Technology for Development in Vienna is the conviction of the developing countries that technology is a key element of development that is outside their control because the world system of science and technology does not work in their interest. Technology meets the demands of the market, and except for a few oil exporting nations, the market is in the developed countries. Within the developing countries, technology meets the needs of the well-off and not those of the poor. Even basic research is strongly influenced by the pull of the market.

If the innovation system is to work on behalf of the developing countries, and particularly on behalf of the poor in developing countries, individual countries and the international community must devise alternatives to the market in order to promote innovation in areas where there is a need but not a demand. A number of efforts in this direction are under way. The most successful and best established of these, the international agricultural research institutes, are internationally funded and directed. Other fields, such as rural energy, will probably lend themselves to development by a decentralized network of institutions in close touch with local needs and prospective users, and perhaps linked by modest international technological services.

However effective these or any other international programs may be, there is no substitute for strong national technological efforts in developing countries, linked as closely as possible to overall economic or sectoral objectives. The existence of these links is critical to the success of technological programs.

Technologists thus face a double challenge: to recognize the potential for new efforts to harness science and technology for the benefit of the developing countries and, by understanding the social, institutional, and economic framework within which an innovation is to operate, to facilitate its use. This means that technologists in developing countries, and those in developed countries with whom they cooperate, must come to understand the global and national social, economic, and institutional context within which technology contributes to development, and to apply this understanding to the design of policy and institutional software that is essential for the effective mobilization of science and technology for development.

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