Chapter 8

Acquiring knowledge in a globalizing world

The process of technological innovation has become intricately linked to the globalization of the world economic system. The shift from largely domestic activities to more complex international relationships demands a fresh look at policies that integrate science, technology, and innovation into economic strategies.

Despite the increasing globalization of technology, the involvement of developing countries in producing new technologies and innovations is almost negligible. The production of technological knowledge is concentrated in industrial countries. There are major differences in the generation of knowledge not only between developed and developing countries but also among developing countries. The challenge facing the global community is to create conditions that will enable developing countries to make full use of the global fund of knowledge to address development challenges.

Enhancing the capacity to use available technologies

Much of the international debate over technology has focused on new technologies and ignored the global context in which such inventions are applied. Globalization of technology falls into three categories: the international exploitation of nationally produced technology, the global generation of innovation, and global technological collaborations (Archibugi and Pietrobelli 2003).

The first category, international exploitation, includes innovators' attempts to gain economic advantages by exploiting their technological assets in foreign markets. Multinational corporations, as the agent of this type of technological globalization, often maintain their national identity, even when their technologies are sold in more than one country. They exploit their technological assets in overseas markets by selling their innovative products, selling their technological knowledge (through licenses and patents), and establishing local production facilities (through foreign direct investment).

Networking technology can be deployed to enable developing countries to benefit from new economic opportunities

The second category, global generation¸ refers to the production of technologies by single proprietors (largely multinational corporations) on a global scale. Multinational corporations use international but intrafirm networks of R&D laboratories and technical centers and one of three main approaches. In the center-for-global approach, the core strategic resources—top management, planning, and technological expertise—are located at a company's headquarters. In the local-for-local approach, the firm's subsidiaries develop their own technological knowledge and know-how to serve local demand and preferences. The interactions among subsidiaries are limited in terms of the development of technological innovations. In the local-for-global approach, multinational corporations conduct their R&D activities in multiple locations.

The third category, global technological collaborations, has grown in importance in recent years. Technological collaborations occur when two companies establish joint ventures or formally agree to develop technical knowledge and products, while maintaining their respective ownership. Many partnerships are between firms located in different countries, thus contributing to technological globalization.

ICT has created a new way of viewing how different industrial, agricultural, and service elements link together in ways that distinguish more than just the economic contribution of these different growth segments. These technologies challenge us to find new ways in which human efforts can enhance institutional life and sustain technological learning in developing economies so that gains in one area can be automatically translated and multiplied as gains in learning in another.

ICT can be applied to meeting the Goals in at least three areas. First, ICT plays a critical role in governance at various levels. Because of the fundamental link between technological learning and the ways societies and their industrial transformations evolve, it is important to situate technological innovation and the application of ICT at the center of governance discussions. Second, ICT can have a direct impact on efforts to improve people's quality of life through better information flows and communications. Third, ICT can enhance economic growth and income by raising productivity, which can in turn improve governance and the quality of life.

The benefits of the new technologies are the result not only of an increase in connectivity or broader access to ICT facilities per se. They accrue from the facilitation of new types of development solutions and economic opportunities that ICT deployment makes possible. When strategically deployed and integrated into the design of development interventions, ICT can stretch development resources farther by facilitating the development of cost-effective and scalable solutions.

Networking technology can be deployed to enable developing countries to benefit from new economic opportunities emerging from the reorganization of production and services taking place in the networked global economy. ICT will become one of the main enablers in the pursuit of poverty alleviation and

One way of creating incentives to work on development needs is to rethink the academic reward system

wealth creation in developed and developing countries alike. At the same time, as a facilitator of knowledge networking and distributed processing of information, ICT can be used to foster increased sharing of knowledge.

A distorted academic reward system is preventing researchers in developing countries from enhancing their nations' scientific and technological capabilities. Academics are rewarded for working on problems of interest to international science, not local problems. Researchers who work on important problems for their country or region risk not being able to publish their findings in mainstream journals or not being invited into intellectual circles of international standing. Changing this system could encourage researchers to work on development problems (box 8.1).

One way of creating incentives to work on development needs is to rethink and "endogenize" the academic reward system. A faster way to create incentives is to organize calls for research proposals directed to solve developmental problems, particularly those affecting the poor (box 8.2). This does not mean that scholars should concentrate exclusively on applied research: often a mixture of basic and applied knowledge is necessary to solve the complex issues that affect poor people.

Another significant problem in developing countries is the absence of demand for value-added and more sophisticated technological activity. One of these technological activities is R&D as it relates to enterprises' collective learning functions—that is, their organizational path to assimilating and innovating new technologies. If this important function is left unattended, enterprises will remain dependent on imported technologies, which are expensive and not adapted for local conditions. If demand for future high-level technological activity is not transmitted to enterprises through appropriate policies, countries run the risk of importing equipment without the complementary generation of domestic innovations. One element of successful interventions in East Asia has been precisely this type of demand-side boost to create incentives for enterprises to invest in R&D and raise levels of R&D spending significantly.

Yet another problem for developing countries is the isolation of their research institutes and laboratories. Commercialization of R&D faces problems

Box 8.1

Venezuela is solving development problems while developing long-term capacity

Source: Avalos and Rengifo 2003.

The Venezuelan National Science and Technology Council developed a new strategy to foster long-term research capacity related to development goals. The strategy consisted of selecting a few large complex problems and funding competitive proposals around them. These proposals encouraged interdisciplinary teams, including firms, to address different aspects of each issue. The problems included those associated with the oil industry, urban violence, and a virus that had attacked the cacao crop. The importance of this initiative goes beyond the results obtained: it points to shifting the academic reward system away from an emphasis on publication to prizing the ability to work on problems related to the nation's wealth and people's well-being.

Box 8.2

Bill Gates' "Grand Challenges in Global Health" is spurring research on health problems affecting the developing world

Source: www.gatesfoundation.org/.

A recent initiative that aims to leverage basic science and engage the world's best scientific minds for health is the Grand Challenges in Global Health, sponsored by the Bill & Melinda Gates Foundation and administered by the Foundation for the National Institutes of Health (Varmus and others 2003). Bill Gates announced the $200 million initiative in January 2003. He described the grand challenge as a call for specific scientific or technological innovations that have the potential to remove a critical barrier to solving an important health problem in the developing world with a high likelihood of global impact and feasibility. The initiative is designed to direct investigators to a specific scientific or technical breakthrough that would be expected to overcome one or more bottlenecks in an imagined path toward a solution to one or preferably several significant health problems.

The Gates Foundation identified the following specific grand challenges:

1. Create effective single-dose vaccines that can be used soon after birth.
2. Prepare vaccines that do not require refrigeration.
3. Develop needle-free delivery systems for vaccines.
4. Devise reliable tests in model systems to evaluate live attenuated vaccines.
5. Design antigens for effective, protective immunity.
6. Learn which immunological responses provide protective immunity.
7. Develop a genetic strategy to deplete or incapacitate a disease-transmitting insect population.
8. Develop a chemical strategy to deplete or incapacitate a disease-transmitting insect population.
9. Create a full range of optimal bio-available nutrients in a single staple plant species.
10. Discover drugs and delivery systems that minimize the likelihood of drug-resistant microorganisms.
11. Create therapies that can cure latent infections.
12. Create immunological methods that can cure chronic infections.
13. Develop technologies that permit quantitative assessment of population health status.
14. Develop technologies that allow assessment of individuals for multiple conditions or pathogens at point-of-care.

Following the announcement of the grand challenges, the Foundation of the National Institutes of Health issued a request for proposals for each of the challenges, with grants totaling $20 million over five years.

of scaling up from laboratory findings to industrial output. There is no easy solution to this problem, except to create opportunities for R&D laboratories in the public domain to work with private industry. In Taiwan (China) R&D consortia are formed to foster cooperation between various laboratories in the government-funded Industrial Technology Research Institute (ITRI) and local small and medium-size enterprises to transfer technologies and develop innovative processes and products (Madsen and Chug 2003) (box 8.3).

Industry associations such as the Taiwan Electrical and Electronics Manufacturers' Association (TEEMA) were involved in identifying enterprises to join R&D consortia and in performing administrative work for the consortia that were established. These R&D consortia are formed to overcome the

Box 8.3

Taiwan (China) has created research consortia and spin-offs

Source: Poon 2002; Hsu and others 2003.

Taiwan (China) has adopted a strategy to blend private and public sources of knowledge with the view to commercialization through group R&D efforts. More than 30 R&D consortia have been formed in Taiwan since the 1980s. These efforts have led to the production of laptop computers, high-definition televisions, videophones, laser faxes, broadband communications, digital switching devices, satellite receiving stations, and smart cards.

The Taiwan New PC Consortium (TNPC) was created in 1994, with the assistance of the computer and communication research laboratories of ITRI. The consortium's members (local manufacturers of personal computers and related computer products) transferred technology from leading information technology firms, including Apple, IBM, and Motorola, in order to make PowerPC microprocessors and products. These products competed with Intel chip–based products.

Private ICT enterprises have spun off from government-sponsored research institutions. United Microelectronics Corporation was the first of a series of spin-off ventures from the government-funded Industrial and Technology Research Institute (ITRI), which created private-sector semiconductor capability. Established in 1980, UMC was a spin-off from the pilot fabrication operations of Electronics Research Service Organization, one of Uteri's laboratories. One of the world's first silicon foundries, Taiwan Semiconductor Manufacturing Company, was created by ITRI in 1986 as a joint venture with the Dutch multinational Philips and a group of Taiwanese firms, with the support of the Taiwan Development Fund. These spin-offs have created a new breed of world-class enterprises that are playing an important role in facilitating technology learning and transfer.

In 2000 the Information Appliances Alliance was formed, with the assistance of the Office of Committee for Information Industry Development and the Market Intelligence Center, which is under the auspices of the Ministry of Economic Affairs. Its aim is to transfer from foreign leading companies the component, hardware, and software technologies required by local manufacturers in the production of information appliances sold in international markets. IAA was established to strengthen the links between Taiwanese manufacturers and overseas organizations competing to define the architectural standards of these new products.

size limitations of small and medium-size enterprises and develop the kind of economies of scale for innovation that are usually enjoyed only by larger firms. Consortium members research and develop products, process technologies, and even technical standards.

Through public-private collaboration of joint R&D, some developing countries have been able to enter a product market right at the beginning of the high-growth stage. Their innovation strategy changed from one of "catching-up" to one of being a "fast follower," able to stay at the leading edge of technology and remain responsive to shifting market trends. Even the "fast-follower innovation strategy" is ineffective as a strategy to upgrade technologically in the face of the changing nature of more dynamic industries, which are essentially an integration of selected industrial sectors. A good example is the ICT industry, which integrates information technology, consumer electronics, and the telecommunications sectors. To overcome such a problem, the government of Taiwan (China) helped local firms form new product consortia and alliances

The ability of developing countries to use existing technologies depends largely on their ability to successfully conduct technology prospecting

to ensure that Taiwanese manufacturers were not left out in the initial stages of developing novel products or new architectural standards considered to have the potential to become popular.

Engaging in technology prospecting

The ability of developing countries to use existing technologies depends largely on their ability to successfully conduct technology prospecting. Technology prospecting entails the searching for, identifying, adapting, and diffusing imported technology. It uses technologies that are readily available, adapting them to the local economy. This process entails both research and enterprise development. It usually involves creating institutions designed to undertake global searches for technology and find ways of adapting them to local and international markets.

One of the best examples of successful technology prospecting is the Fundación Chile, established in 1974 by engineer Raúl Sáez, then Minister of Economic Coordination. Sáez approached the International Telephone and Telegraph Corporation with a proposal to create an institution for research and technology transfer jointly with the government. The private, nonprofit organization was created in 1976 and later authorized by a decree law of the Chilean government.

The aim of Fundación Chile is to undertake "scientific and technological research, its development, and the application to the economy of any advances made…to detect business opportunities, select, transfer, and later disseminate production and marketing technologies that contribute to the country's sustainable development."[1] It implements projects that involve technology transfer, institutional design, and added value based on renewable natural resources. It also promotes the development of human resources. Most of its work has focused on introducing new but proven technologies to the economy.

Fundación Chile creates innovative enterprises, almost always in association with companies or individuals; develops, adapts, and sells technologies to clients in the productive and public sectors, in Chile and abroad; fosters institutional innovations and incorporates new transfer mechanisms; and captures and disseminates technologies to multiple users (as a technological antenna) through seminars, specialized magazines, and project assistance. It has promoted the development of new enterprises in agribusiness, marine resources, forestry, the environment, and chemistry. It created two salmon farming companies that pioneered the industry's boom in the country; developed the technological concept of vacuum-packed beef, introducing centralized slaughtering and later sale of the boxed meat; established quality control and certification of export fruit; and introduced berry crops into Chile.

Fundación Chile creates pilot firms to demonstrate the technical and commercial feasibility of some new technologies, which are then transferred to the economy. Once feasibility is proven and economic profitability established, the

Under the right conditions, foreign companies can contribute to local industrial development by providing capital, markets, and technological and business skills

institution transfers the firm to the private sector. Examples of such transfers include Salmones Antártica, Salmones Huillinco, Salmotec, Finamar, Cultivos Achao, Procarne, Granjanova-Punto Verde, Berries La Unión, Geosig, Tecnoplant, and Auprin. It has sold about 30 of the 40 firms it created to recover the foundation's initial investment and fund new projects.

Attracting foreign direct investment

The global rules for foreign direct investment have changed, as have the modes in which they are most useful. Global production systems have changed the ways in which investment flows and how funds can be made available in certain parts of the world for long-term growth instead of rapid flight to new, cheaper locales. Foreign direct investment needs to be used as a vehicle for carrying tacit knowledge as well as assisting enterprises at the frontiers of world technological learning (Liu and Wang 2003).

Under the right conditions, foreign companies can contribute to local industrial development by providing capital, markets, and technological and business skills (Shi 2001). However, there are many other cases in which foreign direct investment has not contributed much to local technological development (Okejiri 2000). Foreign companies can also increase the local content of their products through subcontracts with local small and medium-size enterprises. Foreign direct investment leads to subcontracting, original equipment manufacturer arrangements, and even own design and manufacture arrangements, creating opportunities for local firms to imitate and learn from the parent companies or contractors.

Governments should promote foreign direct investment. Countries with robust infrastructure, highly trained workforces, and large domestic markets are better able to extract maximum value from foreign companies, particularly multinational corporations. A strategy for promoting foreign direct investment that will contribute to development should target specific sectors and activities. For less developed countries, a good target is commodity diversification and complementary reforms in global trading systems to reform tariff rules that impose an economic penalty on countries that add value to their local material for export.

Upgrading technological capabilities and systems

To move from fast followers to technological leaders, some East Asian developing countries have pursued a "technological diversification" innovation strategy. This approach builds on the strength of their process and prototype development capabilities, adaptive engineering, and detailed design (Lall 2000). Through technological diversification, the late developing firms recombine (mostly known) technologies to create new products or services and expand the company technology base into a broader range of technology areas. This is an attempt to reap technology-related economies of scope (Ernst 2003).

Developing countries can join global value chains by identifying market opportunities and niches

Multinational corporations are now outsourcing some of their R&D activities to developing countries with technological expertise and a good stock of R&D personnel. These are more established channels for local firms in developing countries to learn and upgrade technologically. China, the Republic of Korea, Singapore, and Taiwan (China) are primary locations in which such R&D centers are set up. Specialized R&D clusters have been set up with foreign capital in Indonesia, Malaysia, the Philippines, Thailand, and Viet Nam (Ernst 2003; Chen, Liu, and Shih 2003).

Investing in long-term research capacity in the public sector is most successful when it is tied to specific missions. These can respond to local issues, such as health or environment, or build local capabilities or resources, such as earthquake monitoring. Particularly when it is tied to a threat (such as an earthquake), a mission focus can help generate and maintain critical political support when funding is needed to renew budgets or help disseminate knowledge to users. The challenge is to sustain political support and public interest for more "normal" development problems, which have no short-term fixes.

Private sector capacity can be built in a number of ways, some of which depend on the nature of the industry. In general, however, financial incentives to invest in research equipment or training can help build long-term research capacity. Easing legal restrictions on cooperation among companies can help build networks for shared research. Changing intellectual property laws can help encourage firms to participate in international collaborations that may provide needed information and access to skills. Direct funding for a specific line of research, along with promises of procurement of final products, can also be an excellent way to promote long-term investments in private research capacity.

Joining global value chains

Developing countries can join global value chains by identifying market opportunities and niches. These opportunities will expand as production becomes more globalized. The global economy is now characterized by the integration of trade but the fragmentation of production of goods and services across national boundaries. The global economy consists of many product value chains, which encompass the full range of activities—R&D, design, production, logistics, marketing, distribution, support services—required to bring a product from its conception to its end use and beyond.

These activities are carried out in an unprecedented number of developing and developed countries. Some activities command a higher proportion of value-added than others. To have a chance to climb up the technological development ladder, local firms in developing countries had to first enter the chain and then gradually move up it to engage in higher value-added activities.

An analysis of value chain linkages provides insights into how these linkages facilitate or impede technological and industrial upgrading in developing countries. Policymakers in developing countries need to understand how and

Investing in research on underfunded issues of relevance to developing countries is particularly important in agricultural production, environmental management, and public health

why existing global value chains are structured and function the way they are and how these chains will change over time.

Three variables influence how global value chains are governed: the complexity of transactions, the codification of transactions, and the competence of suppliers. The more complex the transaction, the greater the possibility for global value chains to be organized in one of the three network governance patterns: modular, relational, and captive value chains. Global value chains will be organized as modular supply chains if explicit codification schemes exist to allow easy exchange of complex information between buyers and suppliers and suppliers are competent enough to receive and act on such codified information. If suppliers are not sufficiently competent, buyers may have to keep the activities in-house, leading to more vertical integration, or outsource such activities to a supplier in the captive value chains that have to be tightly controlled and monitored. If a codification scheme in the form of known standards or protocols does not exist, buyers may have to rely on highly idiosyncratic methods based on intensive interaction to work with the suppliers in relational value chains.

Value chain governance patterns will change if any of these factors changes. For example, if a new technology renders an established codification scheme lowering the competence level in the supply base, one might expect modular value chains to become more relational. If there are difficulties finding competent suppliers, captive networks or vertical integration would then become more prevalent. Conversely, rising supplier competence might foster a move of captive networks toward the relational type, and better codification schemes might give rise to more modular networks.

One should not expect such chains to spread automatically or that the East Asian strategy of plugging into such chains can be adopted by other countries. The value chains that drove the East Asian growth, particularly the electronics value chains, may not be accessible to new entrants. The global high-tech production system is now well established in Asia, and China's entry is strengthening its regional cost, productivity, and technology base. Future policy should not be based on the assumption that countries in Africa, the Middle East and North Africa, or most of Latin America and the Caribbean will be to enter these chains. Most developing countries will have to identify niches and opportunities in other value chains.

Conducting research to generate new technologies

Investing in research on underfunded issues of relevance to developing countries is particularly important in fields such as agricultural production, environmental management, and public health. For example, small island states face major sustainability challenges, which require technological responses (box 8.4). There are a variety of ways to channel resources toward pressing development problems that are currently underfunded. First, bilateral donors

Box 8.4

Technological responses to sustainability challenges in Jamaica

Source: P. Paulwell, Ministry of Commerce, Science, and Technology, personal communication, 2004; A. Barnett, Scientific Research Council, personal communication, 2004.

Small island states face a variety of ecological challenges that force them to develop technologies that advance human welfare while protecting the environment. Waste treatment is one of those challenges. Jamaica's Scientific Research Council—a research and development arm of the Ministry of Commerce, Science, and Technology—offers practical domestic solutions to the increasing challenges relating to disposal of wastes and wastewater using environmentally sound technologies. The council has adapted anaerobic technologies, deploying three systems that include biogas reactors, biodigester septic tanks, and upflow anaerobic sludge blanket reactors. So far the Scientific Research Council has commissioned 150 biogas reactors and 13 biodigester septic tanks, and it operates two prototype sludge blanket reactors. These technologies are designed to produce biogas for production activities while reducing municipal and agricultural waste. Unlike in regular septic tanks that discharge into sewage systems, bioseptic reactors release nutrient-rich waste that can used for irrigation after tertiary treatment.

Building on such successes, the country is exploring ways by which it could focus on developing technologies of relevance to small island economies and developing countries in general. This vision is reflected in the focus of the Scientific Research Council, which works closely with other government bodies and academic institutions. In addition to the functions of the ministry, the National Commission on Science and Technology in the Office of the Prime Minister provides overall policy coordination. Other organs of the government that contribute to technological innovation include the Bureau of Standards, Jamaica and the Jamaica Intellectual Property Office. The government has designated November as Science and Technology Month. The government convenes a series of events aimed at popularizing science, technology, and innovation, culminating in the granting of the prestigious awards for efforts in these areas.

could increase their official development assistance to fund research that meets both local and widespread needs and that pass the scrutiny of peer review. Second, bilateral and multilateral donors could join forces, as many have in the past, to sponsor international research centers, individually or through consortia such as the Consultative Group on International Agricultural Research (CGIAR), which have their own science, technology, and innovation advisory bodies and work closely with developing countries. Third, donor support for research could be funded as an international cooperative project in which funds are provided to teams proposing to conduct world-class research that focuses on local or underrepresented research activities.[2]

Agricultural production is an area in which global research efforts make eminent sense. Research on food crops for domestic consumption was long neglected in developing countries, where the emphasis of colonial powers was on export crops. But research conducted in one country can often be of value to other countries. This spillover process can often be accelerated and made more efficient by the presence of a multinational research group that can take a broader and longer term outlook and provide global public goods (Dalrymple 2004).

This concept was first put into practice with the establishment of the International Rice Research Institute (IRRI) in the Philippines in 1960, followed

Donor support for research could be funded as an international cooperative project

by the International Maize and Wheat Improvement Center (CIMMYT) in 1967. Other centers followed. All of these centers were supported by the Ford and Rockefeller Foundations.

In 1972 the CGIAR was established to coordinate and manage the emerging system. The CGIAR was established by the World Bank, with the support of UNDP and national development agencies, such as the U.S. Agency for International Development. It includes a Technical Advisory Committee (recently renamed the Science Council).

The CGIAR initially focused on food production, playing a key role in the Green Revolution. The Green Revolution entailed adapting some semidwarf wheat varieties partially developed in the industrial countries (principally Japan and the United States) to local conditions in developing countries. The process involved not merely relocating seed from one place to another but extensive investment in international and local research. Collaboration with local researchers was very important because of the need to adapt the varieties to local conditions.

The area of pharmaceutical research is particularly affected by the low level of investment in problems that occur in tropical countries (Mrazek and Mossialos 2003). Several proposals have been advanced on how to increase research investment in this area. The proposals range from networks of existing institutions to new technology development alliances, many of which focus on vaccine development. Some have suggested the equivalent of the CGIAR for the health sector. Much of the discussion on addressing this issue has focused on levels of funding and choice of research priorities. But the real challenge lies in designing research systems that take into account interactions between social and technical developments.

Private companies already committed to being good corporate citizens for development could be further engaged in this regard. The first step would be to identify the companies and group them by the sector and region in which they operate. Membership lists of gatherings like the UN Global Compact and the U.S. Council for International Business could be used for this purpose. Targeted messages could be developed for each group. A forum could be provided for discussion among companies, governments, and others to identify specific areas of involvement. The UN Global Compact could be engaged to promote public-private sector partnerships for development among its members worldwide.

Countries can also impose cross-subsidies. Malaysia imposes a cess on the turnover of corporate electricity generators to fund rural electrification and renewable energy development throughout the country (box 8.5). Thirty percent of housing units are required to be low cost; these units are subsidized by the sale of medium- and high-priced units. This policy has enhanced social cohesion in urban centers and helped slow the spread of slums.

Cesses on imports could also spur innovation, although the WTO may object to them. To encourage stock markets to contribute to sustainable development in developing countries, a cess of 0.05 or 0.1 percent of the turnover

Box 8.5

Malaysia uses cess mechanisms to fund research

One way to target sector-specific technological needs is to introduce an industrywide cess. Malaysia has imposed cesses on rubber, palm oil, and timber to fund the Rubber Research Institute, the Palm Oil Research Institute, and the Forestry Research Institute. A cess on tea helps fund research on and marketing of tea in Sri Lanka. Hong Kong (China), Malaysia, and Singapore have all established construction industry development boards. Funding for the boards comes from a compulsory cess on all construction contracts. The revenue is used to build capacity and promote innovations in construction materials and techniques.

A Malaysian project involving government, academia, and industry is the Housing Research Centre at the University Putra Malaysia. Using locally developed building systems and local materials, the center has built experimental houses that are in the process of commercialization. The center's Putra Block, an industrial building system, is patented in the United Kingdom. Malaysia won a gold medal for the system at the International Innovation Expo in Geneva.

of stock markets could be imposed and used to establish a global fund for sustainable development.

Much of the R&D capacity in developing countries is scattered across a wide range of independent research institutions that are not organized around specific technology missions or research programs. As a result, resources are not effectively utilized. One way to address this challenge is to pool resources to pursue research in priority areas identified by national governments.

The Israel Academy of Sciences and Humanities operates a high-level, voluntary, ad hoc Forum for National R&D Infrastructure (TELEM), made up of heads of major national research and funding organizations. Members pool their budgetary resources and catalyze the participation of others to undertake major joint research initiatives in fields of national interest. The members of TELEM include the president of the Israel Academy of Sciences and Humanities (chair); the chief scientist of the Ministry of Industry and Trade; the chief scientist of the Ministry of Science; the head of the R&D Division of the Ministry of Defense; the assistant head of the Budget Department of the Treasury; and the chair of the Planning and Budgeting Committee of the Israel Council for Higher Education. Israel also uses research funds to support and commercialize research (box 8.6).

Given the limited resources in most developing countries, such pooling mechanisms, especially if supported by statutory instruments, could play an important role in advancing local R&D priorities. One important opportunity for such pooling could be through the growing number of regional integration organizations. The East African Community (Kenya, Tanzania, and Uganda) is set to expand to include other countries in the region. The statutory instruments setting up the community as well as its various subsidiary organs offer an ideal opportunity for pooling R&D infrastructure in the region to address pressing challenges in areas such as food security, health, education, and environmental management. Other regional integration organizations in Africa could pursue

Box 8.6

Incremental funding for research in Israel

Source: www.academy.ac.il

The establishment of research funds is emerging as an important mechanism for promoting basic research and commercializing research results. Such funds often start with modest levels and grow over time. The Israel Science Foundation, for example, is now the country's largest and most comprehensive basic research grants program. It began in 1972, with an allocation from the government to the Israel Academy of Sciences and Humanities to promote basic science. The Academy used the funds to set up a modest Basic Research Fund, which, even after a decade of operation, had an annual budget of only about $400,000 (J. Ziv, Israel Academy of Sciences and Humanities, personal communication, 2004).

In 1986 the Israel Academy of Sciences and Humanities issued a report outlining the imminent crisis in Israeli basic research and setting out a master plan that called for substantial increases in national funding. The Israel Academy of Sciences and Humanities enlisted the help of the Israeli government (through the Planning and Budgeting Committee) and the international philanthropic community. With the support of the C.H. Revson Foundation (which contributed $5 million) and other private and governmental donors, it established an endowment fund for basic research. It also convinced the Planning and Budgeting Committee to vastly increase its annual allocation to the Basic Research Fund. Within a decade these Academy-backed initiatives raised the Basic Research Fund's budget by a factor of 10.

In 1992 the Basic Research Fund reconstituted itself as the Israel Science Foundation, now a legally independent nonprofit organization. The Israel Science Foundation's annual budget for 2003 exceeded $53 million (almost all Planning and Budgeting Committee funds); and it is expected to reach $80 million over the next five years. The core of the Israel Science Foundation is still its highly successful competitive grants program for individual researchers. Of the 989 such projects funded in 2003, some 343 were new projects.

The Israel Science Foundation also supports a variety of newer programs designed to help keep Israel internationally competitive in forefront areas of modern science. Equipment grants contribute up to half the total cost of expensive (up to $1.5 million) state-of-the-art equipment systems. Centers of Excellence grants of up to $1.5 million, spread over four years, support multi-institutional, multidisciplinary initiatives in fields of Israeli research strength.

similar strategies. Such collaborative measures could help countries broaden their cooperation through fields that are more pragmatic and less political in character. The example of the Arab Science and Technology Foundation illustrates the potential for such regional cooperation arrangements (box 8.7).

Other ways of generating funds for research include changing the tax laws to give incentives to private individuals and corporations to contribute to research funds and other technology-related charitable activities.[3] This instrument for supporting public welfare activities is now widely used in developing countries. This is partly because of the lack of experience in managing charitable organizations and partly because of the reluctance on the part of finance ministries to grant tax exemptions in fear that it would erode their revenue base. However, it can be argued that areas such as education, health, and environmental management could benefit from the local generation of revenue where specific exemptions are provided by law to encourage the establishment of charitable trusts.

Box 8.7

Promoting regional science and technology cooperation in the Arab world

Source: www.astf.net/; A. Alnajjar, ASTF, personal communication, 2004.

The Arab Science and Technology Foundation was created in 2002 in the United Arab Emirates to promote international cooperation on science and technology among Arab and other members of the international community. It was set up as an independent, non-profit NGO that seeks to bring together Arab scientists at home and in the diaspora. It is a model of regional cooperation that is likely to be emulated by other parts of the world. The foundation is located in Sharjah and plans to set up branches and networks in the Arab world as well as other regions that are willing to enter into collaboration arrangements.

The Arab Science and Technology Foundation enjoys high-level support from his Highness Sheikh Dr. Sultan Bin Mohammed Al-Qassimi, Member of the Supreme Council of the United Arab Emirates, Ruler of Sharjah. The foundation is focusing its research support on such activities of relevance to the region as water resource management, solar energy, and overall environmental management. Its activities are envisaged to expand considerably given its pioneering role. One of its long-term benefits might be to serve as a source of inspiration for the establishment of similar organizations with narrower mandates in the region and other parts of the world.

Forging international technology partnerships

One of the most significant developments in the structure of the globalized economy is a network involving partnering activities. These networks are products of complex interlinkages among a wide range of enterprises, links that are designed to reduce the risks associated with the development of new products and facilitate the exchange of information. These partnering arrangements help provide sources of financing through licensing and upfront fees for R&D expenses, reimbursement of expenses for partnered products and services, royalties, profits, and other "success fees" associated with the achievement of certain milestones. Such arrangements are particularly important in areas with limited access to other forms of financing, such as venture capital. Even where venture capital is available, these arrangements still serve an important risk-reducing function.

Partnering activities are naturally more concentrated in the industrial countries, but these arrangements are being extended to developing countries, especially in agricultural biotechnology. Similar arrangements could be considered in industrial biotechnology. In addition to reducing risk, partnering arrangements can also play a key role in developing technological capabilities in firms and institutions in developing countries. Such capacity would be specialized and related to specific products and services. Such partnering would also be useful in promoting the adoption of good management as industrial production standards in developing countries. It is therefore recommended that partnering models that are relevant to developing countries be identified and promoted as part of the expansion of the new bioeconomy.

One important goal of strengthening the scientific and technological base and improving science and technology policy in developing countries is the generation of new goods and services that can improve health in developing countries. Stimulating the biotechnology industry in developing countries is one way to achieve commercialization of R&D. Forward-looking economic policies have tended to improve conditions for private enterprise in general in recent years, allowing countries with large market potential like China and India to enjoy rapid growth in the private sector. These countries took steps to liberalize their economies and strengthen protection of intellectual property rights in order to create incentives for foreign direct investment. International collaboration between companies may also help foster private sector growth in developing countries (box 8.8).

Recently, Genematrix, an early-stage Korean biotechnology company, entered into a collaborative agreement with Variagenics, a U.S.–based pharmacogenetics company. Through this partnership, Genematrix hopes to gain expertise in applying pharmacogenomics to all phases of drug and diagnostic development. Variagenics will benefit from Genematrix's genomic data from targeted Asian populations.

Box 8.8

International research partnerships build capacity and direct funding toward neglected fields

Source: www.nitd.novartis.com/index.shtml.

International partnerships provide funding for research in neglected fields. One example is the partnership between the Novartis Institute for Tropical Diseases (NITD) and the Singapore Economic Development Board (SEDB), which seeks to make new drugs (initially for tuberculosis and dengue) available to poor people in developing countries at the lowest possible price. The partnership could use differential pricing strategies, financing the research by charging higher prices in developed country markets. It could create additional partnerships for developing, manufacturing, and distributing drugs. Novartis will patent novel compounds, but patents will not interfere with the goal of making drugs affordable for the poor.

The partnership represents a new business model for Novartis and a commitment to social responsibility. Novartis's interest is in broadening its research base in infectious diseases as well as helping find new treatments for diseases that are becoming major public health challenges. The effort is part of the company's effort to fulfill its role as a good corporate citizen through its commitment to the UN Global Compact. Its commercial interests are also clear: it strives to refinance the institute's activities and make it economically sustainable. Novartis retains marketing rights for compounds that have a significant commercial potential in developed markets.

SEDB seeks to strengthen Singapore's technology platform, develop its manpower capabilities, and commercialize technologies and products arising from the NITD. It expects the partnership will have positive spin-off effects, potentially leading to the proliferation of local biomedical start-ups. This example could be replicated, although persuading multinational corporations like Novartis to base a research institute in other developing countries will not be easy. Countries with strong research capabilities can influence the decisions of such firms to base their operations in their territories.

A mentoring scheme—in which an institution or firm in a developed country institution teams up with one in a developed—might be the answer. An institute based in Singapore could mentor one in Bangladesh, where there are opportunities for human resource development through farming out of projects, movement of scientists, and creation of technology incubators and spin-offs. This would encourage Bangladesh to devote more resources to R&D. Such involvement will not take place without a the help of an international agency, which could identify potential partners and promote their collaboration.

Initiatives to help small and medium-size enterprises in biotechnology are a recent and promising development in some countries

South-South collaboration between companies in developing countries can also create new opportunities for entrepreneurs. Cuba's Heber Biotech, a semi-private company, has helped commercialize Cuba's biotechnology products. By 1998 Heber Biotech was recording about $290 million annually in sales of hepatitis B vaccines and pharmaceuticals in 34 countries. Now the company is entering into partnerships with other developing countries. In 2001 it established a joint marketing venture with Kee Pharmaceuticals of India. The company's new division, Kee Biogenetics, has launched India's first recombinant DNA product, streptokinase, capable of dissolving coronary clots and preventing heart attacks. The resulting drug, Cardiostrep, is owned by Heber Biotech. The company aims to use special pricing to access the $11 million Indian market.

Specific initiatives to help small and medium-size enterprises in biotechnology are a recent and promising development in some countries. The eGoli BIO life sciences incubator, launched in 2003, is a business incubator that aims to nurture small, medium, and microsized biotechnology enterprises for commercialization. eGoli BIO seeks to act as a "development conduit for the commercialization of life sciences research, products, services and technology platforms" in South Africa. The company works closely with the Biotechnology Partnership for Development, itself charged with stimulating economic development, contributing to job creation, and building world-class skills and technology platforms to sustain and continue development.

Creating incentives for private enterprise is not likely to be sufficient for private sector growth without simultaneous growth in human capital. China has been trying to attract back its scientists trained overseas through various incentives (some of them, such as limiting the time spent abroad during post-doctoral training, controversial). Critical factors to consider for the growth of private firms in developing countries include the relatively small academic base, the lack of human capital and financial resources, the absence of a market-oriented research culture, the dearth of large national biotechnology companies, and inexperience by academic institutions in mechanisms to transfer research findings to companies.

The linkage between research activities and commercial enterprises continues to be weak in most developing countries. Strengthening this link could help provide fresh stimulus to academic research and re-energize universities. It could also be instrumental in translating basic research into important commercial products, such as molecular diagnostic tools, for local use.

Numerous efforts have been made, especially through the United Nations, to promote South-South cooperation (box 8.9). In additional to regional cooperation arrangements, opportunities for cooperation exist with Brazil, China, India, Malaysia, and Mexico, which could play important roles as technology mentors from other developing countries. Voluntary governmental science and technology agreements are becoming a common feature. The Ministry of Science and Technology in China, for example, has signed such agreements with

Box 8.9

Brazil, India, and South Africa are working together on nanotechnology and efforts to prevent and treat HIV/AIDS

Science ministers from Brazil, India, and South Africa have been working together to identify areas for trilateral cooperation over nanotechnology and efforts to prevent and treat HIV/AIDS. Their first meeting was held in October 2004, as part of the India-Brazil-South Africa trilateral commission. The meeting followed a meeting of the three countries' foreign ministers in Brasilia in 2003. That session identified science, technology, and innovation as one of the key areas for trilateral cooperation.

The partnership was inspired by the low level of investment in research on tropical challenges. This is the first major effort to promote cooperation with a focus on emerging technologies. It is likely that the collaboration will inspire other countries to want to join the group or seek to benefit from the results of the alliance. It is possible that industrial countries will seek to be party to this important initiative, at least indirectly.

96 countries—66 percent of them developing nations (G. Xu, Ministry of Science and Technology of China, personal communication, 2004).

The role of the diaspora in a global economy

Globalizing forces such as connectivity, mobility, and interdependence have made it possible for diaspora communities to strengthen their research and business connections to their countries of origin. The most notable case is the Taiwanese diaspora, which played a crucial role in developing the country's electronics industry (Saxenian 2001). To date this subject has been addressed largely in the context of remittances and other material flows. Attention is turning to possible opportunities that would enable developing countries to build international partnerships with the diaspora (box 8.10).

A number of countries have adopted policy measures aimed at attracting expatriates to participate in the economies of their countries of origin. These measures include investment conferences, the creation of rosters of experts, and direct appeals by national leaders. Efforts to encourage expatriates to return home often occur after countries emerge from periods of civil unrest or economic decline. Like other professionals, expatriates respond to incentives and a sense of purpose. The most important starting point is therefore to establish a clear mission around which the diaspora can rally. The onus is on developing country governments to design programs and offer incentives that enable expatriates to contribute to national efforts.

New barriers to technological learning

The Agreement on Trade-Related Investment Measures (TRIMs) is one of the Multilateral Agreements on Trade in Goods of the WTO. The objectives of the Agreement include "the expansion and progressive liberalization of world trade and [the facilitation of] investment across international frontiers so as to increase the economic growth of all trading partners, particularly developing country members, while ensuring free competition." The TRIMs Agreement

Box 8.10

Switzerland and Singapore are staying in touch with their high-tech expatriates

A number of significant experiments are underway around the world to make effective use of diasporas. The Swiss government has created a consulate (the Swiss House) in Cambridge, Massachusetts, to promote interactions between the Swiss in the Boston area and their counterparts at home. Swiss House was created in recognition of the importance of the area as the world's leading knowledge center, especially in the life sciences. (In addition to Harvard University and MIT, the Boston area is home to more than 50 colleges and universities and a cluster of biotechnology firms.)

In 2002 the National University of Singapore established a college at the University of Pennsylvania to focus on biotechnology and entrepreneurship. The arrangement is similar to its arrangement with Stanford University. It also established the Singapore-Philadelphia Innovators' Network (SPIN), to serve as a channel and link for entrepreneurs, investors, and advisors in the Greater Philadelphia region and Singapore. SPIN seeks to create opportunities for collaboration and partnerships in the area.

India is introducing a number of policy measures—including granting dual citizenship to Indians in countries of strategic interest—aimed at strengthening the role of diaspora in national development. This is a major change of policy, based on the study of how other countries have benefited from their diasporas. These approaches can be adopted by other developing countries, where the need to forge international technology partnerships may be even higher.

Guyana has a population of about 700,000. But nearly 250,000 Guyanans are estimated to live in the diaspora, most of them in New York and Toronto. They contribute significantly to the economy through remittances, but their impact could be even higher if there were a strategic approach to linking them into the economy through technology partnerships.

aims to prevent the adoption and utilization of legislative and other investment-related measures that may cause "trade restrictive and distortive effects" (A. Ratanawaraha, MIT, personal communication, 2004).

The Agreement prohibits trade-related investment measures that are inconsistent with the basic provisions of the 1994 General Agreement on Tariffs and Trade. These measures include local content requirements, which require firms to use at least a specified amount of local inputs; trade-balancing requirements, which limit the purchase or use of imported products by firms to an amount related to the volume or value of local products they export; foreign-exchange balancing requirements, which limit imports by restricting access to foreign exchange; and restrictions on enterprise exports, either by volume or value.

Many governments of newly industrializing countries have expressed concerns that implementation of TRIMs could potentially affect their industrialization and technological development. They fear losing the mechanisms that encourage multinational firms to transfer technology to local firms.

In the process of industrializing, many countries have used innovative mechanisms that promote technology transfers and local learning processes. Several of the development tools that they used were expected to foster technology transfer that came with foreign direct investment. For example, trade-

The priority for most developing countries is technology prospecting, identifying useful technologies and markets for the resulting products

balancing requirements tie the value of foreign investors' imports of raw materials and components to the value of their exports of the finished commodity. Local content requirements mandate that a certain percentage of the components that go into the making of a product be sourced locally. Many countries have used these policy tools to help domestic firms make the transition from low-technology to mid-technology industries.

The TRIMs Agreement prohibited most developing countries from using these measures, beginning in January 2000. The new rules prevented them from maintaining policies that had promoted local firms, enabled greater linkages to the domestic economy, and protected the balance of payments.

Several developing countries, including Brazil, Egypt, India, Indonesia, Malaysia, Pakistan, and Uganda, have requested that TRIMs be amended to provide developing countries the flexibility to continue to use such investment measures to meet their development goals (A. Ratanawaraha, MIT, personal communication, 2004). They argue that these policies are necessary because of the low level of development of the local sector, which would not be able to withstand free competition at this stage. As a result of TRIMs, developing countries may have lost some important policy options for technological learning to pursue their industrialization (A. Ratanawaraha, MIT, personal communication, 2004).

By banning some of the measures developing countries used to foster technological transfer and allow their infant industries to develop, the TRIMs Agreement has forced the governments of these countries to learn how to adapt and to find new policy tools (A. Ratanawaraha, MIT, personal communication, 2004). The question is whether these governments are capable of finding new ways of doing things.

Conclusion

Technological change has become intricately linked to the globalization of the world economy (Lundvall 1999). Traditional technology policy approaches designed in the 1960s and 1970s need to be revised to take into account the globalization of technology. Technology policies need to be rethought in order to exploit existing technologies, generate new ones, and engage in global technological collaborations. Much of the technology needed to advance the Goals is already available. The priority for most developing countries is technology prospecting, which involves identifying useful technologies and markets for the resulting products.