Chapter 2

Acquiring Knowledge

People, firms, and countries use technical knowledge to improve their efficiency in the production of goods and services. Sometimes they create that knowledge themselves; at other times they adopt knowledge created by others. Their decision to create or adopt takes into account the constraints they face. Industrial countries, to expand their knowledge base, invest much time and money in research and development. Developing countries, with fewer resources at their disposal, invest less in R&D; instead, they typically expand their knowledge base by acquiring knowledge created elsewhere and adapting it to their needs.

Despite vast and growing opportunities for tapping knowledge created elsewhere, the income gap between rich and poor countries continues to grow. The challenge for developing countries is to reinforce their capabilities—both human and institutional—so that all sectors, firms, and individuals can acquire, adapt, and use knowledge effectively. The payoffs to doing this well should be enormous. But if it is done poorly or neglected, the knowledge gap between the industrial countries, with their huge capacity to create knowledge, and the developing countries will increase, and the income gap will continue to widen. Indeed, one reason the income gap has not been shrinking is that, in many developing countries, not enough has been done to close the knowledge gap. By contrast, those developing countries that have grown rapidly saw closing that gap as an essential part of their development strategy.

Narrowing knowledge gaps within countries is as important as narrowing those between them. Among 200 firms studied in Kenya, the most productive were found to be 40 times as efficient as the least productive—and the average firm did half as well as the best. If all the firms in the sample were as productive as the firm with the best practice, their total output would have been twice what it was. And if the sample is representative of Kenyan manufacturing generally, bringing all firms to local best practice would yield a 10 percent increase in GDP. Surveys in Ghana and Zimbabwe suggest similar potential gains (Figure 2.1).

The gains would be even greater if these developing countries could be pushed to international best practice. Average productivity in spinning in Kenya was found to be 66 percent that in England. Assuming a similar gap between best practice in Kenya and that in England (and using England as the reference for international best practice), Kenyan firms could enjoy a 50 percent jump in manufacturing output—and an additional 5 percent increase in GDP—if they were to produce at international best practice. This back-of-the-envelope calculation shows the large dividends available from closing knowledge gaps within and between countries.

Similarly large gains from making more effective use of existing knowledge can be achieved in such areas as health and agriculture. The technology already exists to deal with many of the infectious diseases that afflict developing countries. The challenge is to disseminate this knowledge effectively, especially to the poor.

This chapter has two main themes:

- *Acquiring technical knowledge from the world.* For most developing countries, tapping into the global stock of knowledge is critical. And in their strategies for acquiring knowledge, they have to take intellectual property rights into account. For their part, national and international policymakers must strike the right balance between preserving incentives to create knowledge and discouraging efforts to disseminate it.

- *Creating technical knowledge at home.* If it is to be used productively, imported knowledge must be adapted to local circumstances. Moreover, developing countries must not only do better at adopting imported knowledge, but also create new knowledge and exploit the knowledge they have, to meet local needs. They also need to make better use of their own R&D.

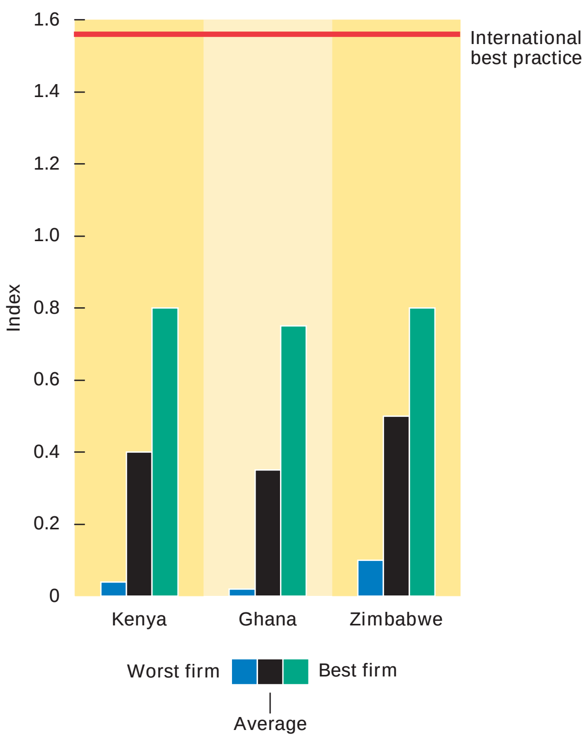
Acquiring global technical knowledge

Industrial countries lead the way in the development of new products and processes. Eighty percent of the world's R&D and a similar share of its scientific publications come from the more industrialized nations. For developing countries, acquiring knowledge from abroad is the best way to enlarge the knowledge base. Indeed, one of the clearest lessons from Japan and the newly industrializing economies in East Asia is the value of importing—and building on—established technology from abroad. Developing countries, whatever their institutional disadvantages, have access to one great asset: the technological knowledge accumulated in industrial countries. They should tap this global stock of knowledge, and government should support the private sector in that endeavor.

Figure 2.1

Productive efficiency in firms in three African countries

Productivity varies widely even within developing countries.



Note: Data are from a survey of manufacturing firms in the three countries in 1992–93. The index is calculated such that 1 equals the maximum efficiency achievable, given the quality of available inputs and the policy environment, among all firms in the sample. Source: Biggs, Shah, and Srivastava 1995.

Tapping global knowledge

The liberalization of trade and regulatory regimes in many countries and the falling costs of transportation and communications are making the world economy more interconnected—more global. Both trade in goods and services and foreign direct investment (FDI) have increased, as have international travel and migration. Here we briefly review the roles of trade, FDI, technology licensing, and the international movement of people as the principal channels for acquiring imported knowledge. (Others not discussed here include strategic alliances, technical assistance, and electronic interchange.)

International trade. Trade can bring greater awareness of new and better ways of producing goods and services: exports contribute to this awareness through the information obtained from buyers and suppliers, imports through access to the knowledge embodied in goods and services produced elsewhere. And as trade becomes ever more driven by knowledge, the opportunities for acquiring technical knowledge will expand. Since the 1970s the structure of international trade has changed significantly: formerly dominated by primary products (such as iron ore, coffee, and unprocessed cotton), it is now concentrated in technology-intensive goods (Figure 2.2). High-technology goods alone doubled their share of world merchandise exports from 11 percent in 1976 to 22 percent in 1996. Meanwhile the share of primary products dropped to less than 25 percent, from about 45 percent initially.

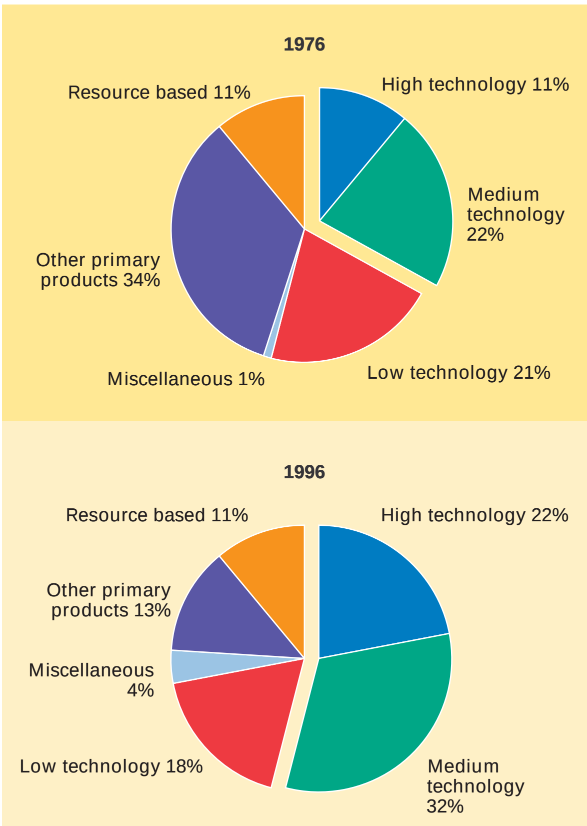
Exports expose firms to global benchmarks of quality and design. They allow firms to realize economies of scale, by expanding production beyond what is possible in the domestic market. An export orientation also induces efficiency, through pressures to compete in the global marketplace. And to compete with best-practice firms in other countries, exporters tend to invest more in knowledge than do firms that serve only the home market.

To expand their trade, countries also need good standards, measurement, testing, and quality control systems. These constitute the infrastructure for technical activity, and their significance grows as traded products and services increasingly have to conform to world standards and regu-

Figure 2.2

Goods in international trade by level of technological intensity

Technology goods have greatly expanded their share of global trade.



Note: Medium- and high-technology goods are those requiring intensive R&D as measured by R&D expenditure. Source: World Bank COMTRADE database.

lations. If consumers cannot readily distinguish between products or services of differing quality produced by different firms, poor quality by one producer in a market can damage all others, in extreme cases closing entire markets. In Latin America in recent years, substandard quality in a few export shipments—contaminated fruit, shrunken textiles—led North American retailers to shun all such exports from the originating country for months. Obtaining certification for meeting quality standards is especially important for countries with a reputation for poor products (Box 2.1).

Foreign direct investment. Large multinational firms are global leaders in innovation, and the worldwide spread of their productive activities is an important means of disseminating their knowledge to developing countries. The size of their knowledge base is reflected in the fact that the 50 largest industrial-country multinationals accounted for 26 percent of all corporate patents granted in the United States from 1990 to 1996. The knowledge in multinationals spills over through learning by their workers and domestic suppliers and through technology sales (royalties, licenses, patent rights). In Malaysia the local affiliate of the U.S. firm Intel Corporation now subcontracts a range of its activities to firms set up by some of its former engineers.

The benefits to a developing country from FDI depend largely on its trade and investment policies. Countries with protected local markets are likely to attract such investment, but only for the purpose of jumping the tariff walls. The technology that enters is then likely to be the older and more inefficient kind, since it need compete only with similarly protected domestic firms. Countries with more-open trade regimes are more likely to attract competitive, outward-oriented foreign investment, which

Box 2.1

ISO 9000: Signaling quality and improving productivity

The ISO 9000 series of international quality management standards lays down detailed procedures for ensuring quality at all stages of production and requires strict documentation of adherence for firms seeking certification. In 1988 existing national standards of quality for manufacturing and services were adopted by the International Standards Organization (ISO) and published under the ISO 9000 name. ISO 9000 certification (which applies to the whole production process, not specific products) signals quality in markets, and international buyers often insist that their regular suppliers obtain this seal of approval.

A 1995 survey by the United Nations Industrial Development Organisation cited demand from overseas customers as the main impetus for ISO 9000 certification by Asian and Latin American exporters. Among 93 major Brazilian enterprises surveyed in 1994, 55 percent increased productivity as a result of ISO 9000, 35 percent improved the standardization of processes, 31 percent increased employee participation in quality control, and more than 20 percent reported an increase in client satisfaction.

Indian chemical companies have also worked to obtain ISO 9000 certification to reassure their Western buyers about the quality of their products. In 1993 Sudarshan Chemical Industries became the first Indian chemical company to receive certification. The process took 15 months, and before applying the company had been working on total quality management for about five years. More than 95 percent of its deliveries are now on time (up from 70 percent). And the margin of error in its product quality has been reduced from 6 percent to 1 percent, and that in new material quality from 4 percent to 1 percent.

brings more efficient technology and management. Whether that investment also generates spillovers for the host country depends in part on the competitiveness of local suppliers, which in turn depends on their capabilities and access to inputs at world prices, and on the supporting domestic infrastructure (Box 2.2).

Spillovers also depend on linkages between the foreign-owned establishments and the rest of the economy. Yet often foreign companies operate in enclaves, with few local ties—and thus few opportunities to transfer knowledge. A prominent example is the *maquiladoras*, the assembly plants on the Mexican border with the United States. Maquiladoras operate in a wide variety of industries and range in size and sophistication from small plants stitching garments to sprawling electronics assembly plants with hundreds of employees. From their origins in 1965 employment in maquiladoras has grown to more than 800,000 workers at nearly 3,000 locations. Aside from this employment (mostly of low-skilled workers), the plants have few links with the Mexican economy, based as they are on processing imported U.S. inputs brought in under special tariff exemptions.

A major attraction to FDI in today's global economy is a sophisticated communications and transport infrastructure, and here developing countries are at a disadvantage. Many also suffer from an unstable economic, political, or social environment. As a consequence, despite the sizable increase in FDI to developing countries in the past decade, most of that investment goes to only a few countries. The majority of countries benefit only marginally, and Sub-Saharan Africa receives only around 1 percent of the total (Figure 2.3).

If developing countries are to get more global knowledge, they need to attract more FDI. Governments in countries where the investment climate is perceived to be risky can, in the short run, facilitate FDI by working with such international agencies as the Multilateral Investment Guarantee Agency (an affiliate of the World Bank), or with other insurance programs, public or private. But attracting FDI is more a matter of the long than the short run. Many countries, including some in Africa, have instituted policy reforms and maintained them over an extended period (five years or more), have achieved high levels of economic performance, and have worked hard to create an environment friendly to foreign investment. Yet that investment has been slow in coming. Investors also seem to be slow in distinguishing countries with good prospects from those with poor. Over time, however, investors should become better informed, and investment flows should increase to those countries that distinguish themselves by their sound policies.

Technology licensing. Licensing of foreign technology has become an important mechanism for developing countries to acquire knowledge. Licensing and royalty payments increased from $6.8 billion in 1976 to more than $60 billion in 1995. Technology licensing is an effective way to get access to some of the new proprietary technologies and can be much more cost-effective than trying to develop an alternative technology. The learning that accrues from using more advanced technology can play an important role in closing the knowledge gap and thereby promote long-term

Box 2.2

How to attract technical knowledge through trade and foreign investment—and how not to

Openness to world markets makes it easier to acquire international technology, capital goods, and ideas—and to grow faster. A study of the factors driving economic growth in 130 countries found a statistically significant, positive relationship between growth in GDP per capita and the ratio of exports plus imports to GDP. In another study, exports of fast-growing economies averaged 32 percent of GDP; in the slower-growing economies that figure was only 20 percent. One of the prime reasons for the growth spurt of the East Asian economies was their ability to build strong links with world markets and acquire the technology flowing through them. They accomplished this with policies ranging from complete liberalization (in Singapore, for example) to aggressive export promotion (in Korea).

Countries in the Middle East and Africa have recently offered institutional incentives to exporters through free trade zones. However, these for the most part have been poorly managed, and tariffs on imports have remained relatively high. Exporters have faced prohibitive tariffs on the import of inputs (35 to 50 percent), and import licenses, where available, have been difficult to obtain.

Productivity growth and economic growth also come from openness to the foreign ideas and technology associated with FDI. This process typically begins with the local buying offices of international purchasers, which are an important source of production and marketing knowledge. Hong Kong (China), Indonesia, Malaysia, Singapore, Taiwan (China), and Thailand have been particularly welcoming to FDI, and their growth spurts have been closely associated with surges in foreign investment. These inflows can be attributed to a hospitable environment for foreign investment, along with favorable external conditions.

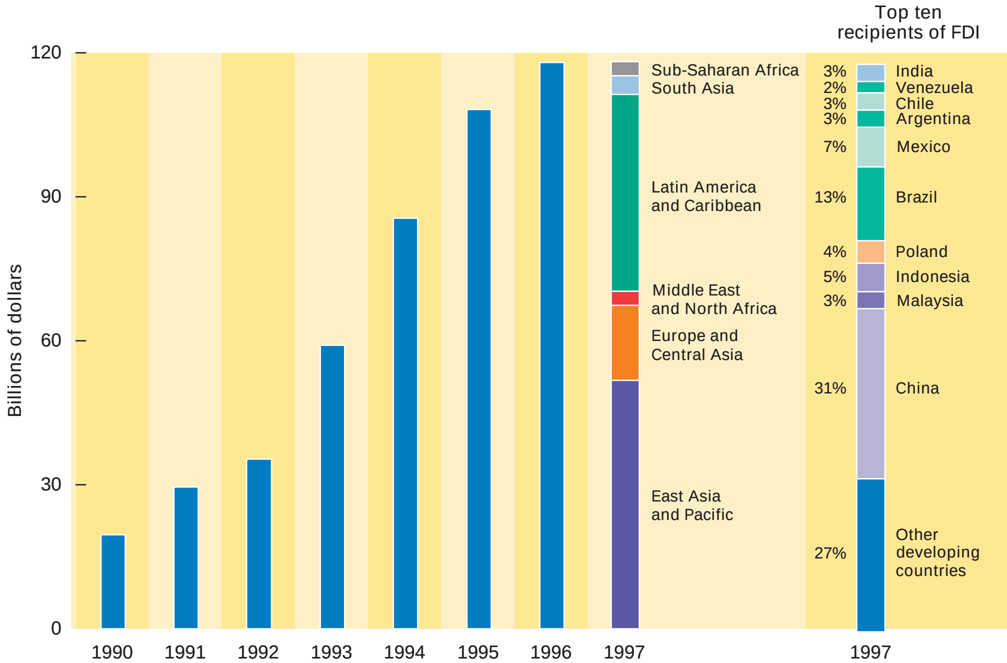
The opposite has been true in the Middle East and Africa. Countries there have received very little foreign investment, as a result of several impediments:

- Insecure property rights, a critical element of a market-friendly institutional environment
- Severe restrictions on the ownership of businesses by foreigners (and excessive regulation generally)
- Weak infrastructure, and
- An unhealthy macroeconomy, with chronically high fiscal deficits, high and unstable inflation, and fluctuating growth rates.

Figure 2.3

Trends in FDI flows in developing countries

FDI in developing countries has risen severalfold in this decade—but remains concentrated in a few markets.



Source: World Bank 1998d.

development. Domestic firms can also use licensing explicitly to leverage their technological development by negotiating access to the underlying design principles of the licensed technologies in areas they are interested in developing further, as many Korean firms have done.

The information differences between the parties to a technology licensing agreement may, however, limit the agreement's potential scope. Not knowing the true cost and quality of the technology on offer, licensees risk choosing outdated or poor-quality technology. Licensers, for their part, may fear that licensees may try to renege on the contract after mastering the knowledge, and this, too, may block some transactions. Some countries have addressed this problem by creating information centers for domestic firms, where they can learn the ins and outs of foreign technology markets, and thus reduce their disadvantage in licensing negotiations. Another option is reputation building through the prospect of repeat contracts and linking royalties to the output of the licensee.

During the 1950s and 1960s, in an effort to weaken the bargaining power of foreign licensers, Japan's Ministry of International Trade and Industry managed the source and type of technology licensing by Japanese firms. This reduced the cost of acquiring knowledge from abroad. Some developing countries have likewise tried to boost their bargaining power by restricting technology import contracts or capping royalty rates. But if countries lack market power, these restrictions can backfire: free to take their business elsewhere, licensers may not find it worthwhile to transfer technology under the restrictive terms.

Travel and migration. Some developing countries have experienced large inflows of skilled immigrants, who have brought with them specialized knowledge and in some cases have maintained knowledge links to their home countries. Other countries have imported technical knowledge embodied in the human capital of hired foreign experts. International technical assistance and international consulting also involve the movement across borders of people with specialized technical knowledge.

Developing countries can also benefit from (temporary) outflows of human capital: travel to the world's technological centers can be a very effective means of acquiring foreign knowledge. After World War II, under the Marshall Plan almost 20,000 Europeans traveled to U.S. plants to observe advanced manufacturing and management technologies firsthand. The trips proved very useful for setting up and improving the productivity of similar plants in Europe.

On a smaller scale, many businesses, universities, and research centers organize formal exchanges and study tours to share knowledge. These trips include visits to trade fairs, meetings of professional societies, and conventions. Governments, the World Bank, and other international development institutions also organize such visits, so that technicians and policymakers can learn about best practices from industrial countries or from other developing countries.

The opposite side of this coin is the still-ongoing brain drain from the developing to the industrial world. More than 1 million students from developing countries are getting their tertiary education abroad; many of them, especially those earning doctorates, never return home, finding the opportunities there few and the pay low. Some of the best students trained in the developing countries themselves also emigrate, for the same reasons. Both types of emigrants represent a serious loss, all the greater because their education is often fully or partly subsidized by their governments.

Some developing economies have launched programs to recoup these investments, with Korea and Taiwan, China, the most successful. Both have tried to repatriate brains by offering good job opportunities and strong financial and tax incentives to those who return home to teach or work. And some—such as China, India, and again Taiwan, China—have successfully tapped the expertise of their overseas nationals, even without bringing them back. Emigrés often work in high-technology firms and are well aware of market trends and niches. They are thus well placed to give useful technical and market information to producers back home. And they can serve as brokers in trade and other deals between home-country nationals and foreigners.

Another important source of knowledge is other developing countries. For knowledge flows do not just run in a single, one-way current from industrial to developing countries. A growing volume of knowledge is shared among developing countries. This includes technology that has been adapted for specific developing-country conditions as well as local knowledge. Countries now in the earlier stages of development have much to learn from the successes and failures of today's industrializers, for they, too, were on the lower rungs of the development ladder not so very long ago. Knowledge also flows from developing to industrial countries. These include not only indigenous knowledge—for example, about the curative properties of certain indigenous plants, the fruit of some developing countries' biodiversity—but also some modern technological innovations. All these flows—among developing countries and between developing and industrial countries—can be expected to increase.

Public support for technology transfer

Using and misusing incentives. To acquire knowledge through trade, FDI, or licensing, firms must often be encouraged to engage in a conscious and ongoing effort to learn and adapt technology. But the efforts of firms are difficult for government to monitor. Firms protected from price competition may fail to adapt rapidly and efficiently to new technologies or to lower long-run costs. By creating economic rents for incumbents in the protected industry, governments can induce wasteful lobbying as firms devote their efforts to seeking government favors rather than becoming competitive. Protection may dilute firms' incentive to search for the best technology, to invest in training, and to adapt and upgrade their designs.

For example, there is evidence of nonlearning due to misguided protection in the transfer of textile technology to certain African countries. Few resources were committed to searching for superior technological alternatives, and operating efficiency did not increase over a long period of high subsidies. By guaranteeing the profitability of the textile industry through tariffs, price harmonization, and import licensing, Côte d'Ivoire actually diminished the incentive to move toward more efficient production. Evidence from the early 1960s through the late 1970s shows that, despite extensive government intervention, Côte d'Ivoire's textile industry did not develop local technological capability, nor did it graduate from reliance on expensive expatriate staff or produce spillovers in the economy. The outcome was that improvements in labor productivity and capacity utilization rates, where data are available, were mostly slow.

Brazil's attempt to develop a national computer industry illustrates the difficulty of building an industry under a strong protectionist regime. In the mid-1970s the government reserved to national producers that segment of the computer market ranging from submicrocomputers to home computers, peripherals, and subassemblies. To do so it banned not only imports but also FDI. A government agency identified areas for national production, solicited bids from Brazilian firms, and awarded production licenses. It also set up a public research center for informatics and established special fiscal incentives for informatics R&D. By the mid-1980s this policy had succeeded in developing a large national industry. But protection left the industry too fragmented, with many manufacturers producing at less than efficient scale. The domestic component industry was also weak and inefficient, and exports

Box 2.3

Korea: The success of a strong interventionist state

A widespread view holds that Korea's growth was market-led, a result of opening to international markets. But some researchers argue that what is behind the emergence of this Asian "tiger" is a strong, interventionist state—a state that deliberately and abundantly granted tariff protection and subsidies, manipulated interest and exchange rates, managed investment, and controlled industry using both carrots and sticks. Relative prices were deliberately set "wrong," to generate and reap the benefits of evolving comparative advantage, instead of letting them adjust to the "right" levels by the free play of market forces. Korea's leaders judged that getting prices right would lead to short-run efficiency but long-run economic anemia.

Korea's development strategy has been mainly one of pragmatic trial and error, based on a twofold commitment: to the growth of exports and to the nurturing of selected infant industries through protection. The encouragement of exports, particularly manufactured exports, became an active policy in the early 1960s, following unsuccessful attempts at import substitution in the 1950s. It involved the establishment of virtual free trade regimes for exporters through detailed systems of duty drawbacks for direct and indirect exporters. The incentives available to exporters included direct tax reductions, privileged access to import licenses, and preferential interest rates. Thus export promotion entailed substantial government involvement.

Korea chose to focus first on low-technology products, in which the gap between the skills required and those available locally was not large. This had two effects: it encouraged learning-by-doing, and it made Korean firms less dependent on foreign expertise. In the early 1960s, targeted industries included cement, fertilizers, and petroleum refining. In the late 1960s and early 1970s the focus shifted to steel and petrochemicals, and in the late 1970s shipbuilding, capital goods, durable consumer goods, and chemicals were targeted. More recently, electronic and other component industries have been given preference.

At each stage, these industrial policies have engendered controversy. Advocates point to the bottom line: between 1955 and 1991, Korea's GDP per capita increased sixfold. Critics suggest that Korea's growth would have been more rapid still without these policies. To be sure, not every decision seems in retrospect to have been a good one; but the same can be said about any complex private enterprise, without government involvement. The investments in petrochemicals may have looked like a mistake after the huge increases in oil prices in 1973, but no one could have anticipated those price changes. Moreover, with oil prices lower today in real terms, Korea's petrochemical investments look much smarter—perhaps one has to take a longer perspective. In any case, these and other technology investments in the 1970s enabled Korea's petrochemical firms to move up the technology chain, closing the knowledge gap.

were low, consisting mostly of printers. Prices for Brazilian computers were significantly higher than international prices, and the computers were usually a generation behind the latest models abroad. This policy was finally reversed in 1992 with the liberalization of the informatics market.

A key role of a competitive price system is to reveal minimum costs of production. Markets with free entry are like contests: profits depend on performance. Governments that create protective walls around an industry remove this discipline and shut off the information flow that markets sustain. Policies that promote new industries must, to the extent that they replace the market contest system, find an alternative that ensures continuing efficiency if they are to succeed.

Many East Asian economies did this partly by granting subsidies largely on the basis of rules and performance, allowing little bureaucratic discretion. Firms that successfully entered export markets got preferential access to credit. There is some evidence that making subsidies contingent on export performance promoted the use of technology sophisticated enough to compete in world markets and ensure that learning kept pace with the technological frontier. East Asian governments also devised ways of better controlling the bureaucracy (for example, through job rotations), which limited the opportunities for corruption. Although export subsidies are not now permitted under World Trade Organization (WTO) rules, there is still much to learn from the strategies followed by the East Asian economies.

National strategies. Governments in many countries have played a large role in the development and application of technology. The U.S. government built the world's first telegraph line between Baltimore and Washington in 1842. Government-provided agricultural research and extension services are generally credited with much of the enormous increase in agricultural productivity in the 135 years since they were initiated. The Internet, which is changing the way information is exchanged throughout the world, was developed in the United States through public grants.

In the past 50 years, among the handful of economies that have come a long way toward closing the knowledge gap with the global technological leaders, government was active in several, including Japan, Korea, and Taiwan, China. Korea followed a strongly interventionist and nationalist route, keeping FDI to a minimum and relying instead on other modes of technology transfer and a concerted domestic technological effort (Box 2.3).

Although the government of Taiwan, China, was also actively involved in promoting industry, its policies differed in many ways from those of Korea. Rather than supporting a few large enterprises that were particularly successful in developing exports, the Taiwanese based their growth strategy on small and medium-size enterprises. Like Korea's giant *chaebol*, however, the small Taiwanese firms also sought to import high levels of technology. And although the Taiwanese did not erect the barriers to FDI that Korea did, neither did they base their development on the wholesale recruitment of FDI as some other economies have done.

Two other East Asian tigers followed more conventional outward policies and assigned a different role to government. Hong Kong, China, consistently a free trade economy, adopted a liberal stance toward technology acquisition, leaving private firms to choose whatever means they preferred. The city-state provided a free trade, low-tax, stable environment for all investors, regardless of origin. Coupled with a strong base of Chinese entrepreneurs and well-developed trade and financial sectors, this led to the growth of a vibrant, export-oriented industrial sector specializing in relatively low technology activities based largely on domestic enterprise. But the real success of Hong Kong, China, is as an entrepôt, a commercial trading post between China and the rest of the world.

Singapore, which also has a largely free trade regime, chose to rely on foreign investment, which it actively encouraged, and to move that investment into increasingly complex and scale-intensive technologies. Among developing countries, Singapore has relied the most on FDI, which it attracted initially with disciplined, low-cost labor. With this success in luring investment, wages rose. To continue to make Singapore an attractive location, the government has had to build physical infrastructure. Its seaport, airport, and telecommunications infrastructure are now among the most modern and efficient in the world. And having invested heavily in technical education and training, Singapore now boasts one of the world's most highly skilled labor forces.

The evolution of intellectual property rights

Many of the newly industrializing economies in East Asia imported much of their technical knowledge at a time when enforcement of IPRs was not as strong as it is today. Of late there has been a determined move, coming mainly from industrial countries, to strengthen IPRs. In 1994, at the conclusion of the Uruguay Round of multilateral trade negotiations that led to the creation of the WTO, a new agreement on trade-related aspects of intellectual property rights (TRIPs) strengthened IPRs in WTO member countries while allowing developing countries a transition period (Box 2.4).

IPRs are a compromise between preserving the incentive to create knowledge and the desirability of disseminating knowledge at little or no cost. Without a system

Box 2.4

TRIPs in a nutshell

Intellectual property rights are created by national law and thus apply only in a single national jurisdiction, independent of such rights granted elsewhere. Establishing a global IPR regime thus requires cooperation among national governments to harmonize their separate laws. Numerous international treaties to promote such cooperation have been negotiated over the past 100 years. Most are administered by the World Intellectual Property Organization (WIPO), a specialized agency of the United Nations. WIPO conventions—for example, the Paris Convention for industrial inventions and the Berne Convention for copyright of literature, art, and music—require their signatories to grant national treatment (foreign firms are treated the same as domestic ones) in the protection of IPRs, but typically do not impose common standards of protection. New global rules on IPRs are forcing a reassessment of past strategies for acquiring, disseminating, and using knowledge.

The 1994 TRIPs agreement builds on existing WIPO conventions and lays the foundation for global convergence toward higher standards of protection for IPRs. It requires signatories to apply the principles of national treatment and most-favored-nation (MFN) status to intellectual property protection. Unlike most other international agreements on IPRs, the TRIPs agreement sets minimum standards of protection for all forms of intellectual property: copyright, trademarks, service marks, geographical indications, industrial designs, patents, layout designs for integrated circuits, and trade secrets.

In each area the agreement defines the main elements of protection: the subject matter to be protected, the rights to be conferred, and the permissible exceptions to those rights. For the first time ever in an international agreement on intellectual property, the TRIPs agreement addresses the enforcement of IPRs by establishing basic measures to ensure that legal remedies are available when infringement occurs. Disputes between WTO members over TRIPs obligations are subject to the same dispute settlement procedures that apply to other WTO agreements.

The provisions of the TRIPs agreement became applicable to all signatories at the beginning of 1996, although developing countries are entitled to a four-year transition period, except for obligations pertaining to national and MFN treatment. Developing countries are entitled to an additional five-year transition for product patents in fields of technology not protected before 1996 (this applies to pharmaceutical products). The least-developed countries are granted a transition period extending until 2006, again excepting for national and MFN treatment.

that protects the rights of those who create knowledge, it is unlikely that individuals and firms would spend much to do so, or at least as much as others do. Patents, for example, provide to knowledge creators the legally enforceable power to exclude others from using their knowledge for a specified period (17 years in the United States). However, the importance of patent protection differs across industries. It is more important in industries such as pharmaceuticals and specialty chemicals, where products tend to be long-lived and it is relatively easy to copy a formula, than in industries such as electronic products, where product cycles are very short and secrecy may be a more effective exclusion strategy. IPRs are important because the cost of developing new products can be quite high. In the pharmaceutical industry the investment necessary to develop, test, and market a new drug is estimated to average $200 million in the United States.

It is expected that stronger IPRs would lead to greater R&D effort in countries that offer such protection. There is limited empirical evidence, however, of the impact of IPR protection on increased investments in R&D, even in industrial countries. In part this reflects difficulties in establishing causality, for not only may IPRs stimulate more research, but also the demand for protection may be higher in countries that invest more in R&D. The benefits of patents, however, go beyond stimulating investment in R&D. Patents provide published information to other researchers, who can then develop innovations in similar directions to meet new needs.

It is also sometimes argued that stronger patent protection in developing countries could stimulate research in industrial countries on issues of concern to developing countries (such as tropical diseases). Once again, the empirical evidence is limited, although it is reasonable to expect that IPR protection may be a necessary, but not a sufficient condition for private companies to engage in such investment.

Because developing countries often use knowledge produced in industrial countries, they have a particular interest in its dissemination. But without some protection of intellectual property, firms in industrial countries will have no incentive to transfer knowledge, or even to make investments that might lead to such transfer. The level and quality of patent protection in developing countries therefore influence both FDI and direct technology transfers through licensing agreements and the vertical integration of multinational firms—both important for the diffusion of knowledge (Box 2.5). IPRs also help create a market for knowledge by providing a legal basis for technology sales and licensing. They signal to prospective investors that a country respects their intellectual property and is "open for business" according to accepted international norms. And IPRs can encourage multinational companies already established in a developing country to transfer more technology-intensive functions, including R&D, to their affiliates, as well as the knowledge embodied in products that are fairly easy to replicate.

Box 2.5

IPRs, investment, and technology transfer

A World Bank study found that the strength or weakness of a country's system of intellectual property protection has a substantial effect, particularly in high-technology industries, on the kinds of technology that many U.S., German, and Japanese firms transfer to that country. This strength or weakness also seems to influence the composition and extent of FDI in the country, although effects seem to differ from industry to industry.

In chemicals and pharmaceuticals, at least 25 percent of firms surveyed in all three countries felt that protection in Argentina, Brazil, Chile, India, Nigeria, and Thailand was too weak to allow them to invest in joint ventures where they contributed advanced technology. In machinery and electrical equipment, the same was true of Brazil, India, Nigeria, Taiwan (China), and Thailand.

More than a quarter of chemical and pharmaceutical firms in the three source countries felt that IPR protection in Argentina, Chile, and India was too weak to permit them to transfer their newest or most effective technology to a wholly owned subsidiary there. And more than 20 percent of machinery and electrical equipment firms in the source countries felt that this was the case in Brazil, Nigeria, and the Philippines. Hong Kong (China) and Singapore were felt to have the strongest protection among the major economies considered.

Many developing countries have begun to reform their IPR regimes. The number of developing countries that have signed the Paris or the Berne Convention increased from almost 50 in the 1960s to more than 100 by the mid-1990s. As a result of the more stringent demands of the TRIPs agreement that went into effect in 1996, and of the increasing realization of the importance of knowledge in their own economic activity, one may expect that more developing countries will strengthen their IPR protection.

Despite the pluses, the effects of IPRs on developing countries raise several concerns. Tighter IPRs may lead to a higher cost of acquiring knowledge. They shift bargaining power toward producers of knowledge, and away from its users. Since knowledge is a key input in the production of more knowledge, stronger IPRs may adversely affect follow-on innovations, in developing as well as industrial countries, that draw on inventions whose patents have not yet expired. There is thus a concern that tighter IPRs may actually slow the overall pace of innovation. However, there is no systematic empirical evidence confirming this, just as there is none on the positive impact of IPRs on increased R&D. A related concern is that, with patented knowledge, the pace of imitation may be slowed, and the knowledge gap between industrial and developing countries may increase.

Tighter IPRs can thus disadvantage developing countries in two ways: by increasing the knowledge gap and by shifting bargaining power toward the producers of knowledge, most of whom reside in industrial countries. This raises a concern about the distributional effects. These may be particularly strong with respect to the effects of patents on the price of medicines, because of the relatively weak bargaining power of developing countries in negotiating prices with monopoly suppliers. Fears about this may be exaggerated, however. Some argue that the knowledge most needed by the poorest—for example, to produce most of the drugs they might use—is already in the public domain, mostly because the patents have expired. Moreover, these dangers have to be set against the advantages of tighter IPRs already described. A desirable IPR regime is one that balances the concerns of all parties affected by strengthened IPRs.

There are many dimensions to IPRs, and adjustments strengthening or weakening protection may affect developing countries in different ways. These should be taken into account as the IPR agreements evolve. The easiest to explain is the life of a patent: longer patent lives give the inventor more protection. Although patent lives have been standardized to a considerable degree, a variety of other issues remain. For instance, given the long delays in government approval, should the life of a drug patent begin only after the drug has received approval? or from the time the inventor applies for the patent? Standards for determining whether a product is novel enough to claim patent protection, and for determining how broadly such protection should apply to related products and processes, are complex issues, and changes can have enormous effects. Broad patents may, for instance, jeopardize the prospects of anyone attempting to adapt the technology in question to different circumstances.

Developing countries face new IPR challenges in biotechnology. Industrial-country breeders are relying on the regular patent systems for protection of agricultural biotechnology products and processes. Breeders enjoying such protection can prevent their competitors from using their protected material for breeding purposes—they can even prevent farmers from reusing harvested seed. In pharmaceuticals and biotechnology, shortly after the new research tools of molecular genetics were developed, patent systems in industrial countries began to provide protection for a variety of these innovations, such as the fundamental mechanism of gene splicing. These protections affect the processes for producing a variety of products and therefore go far beyond the protection of a specific pharmaceutical or other product.

Strong IPRs can also affect traditional knowledge. One issue is how to compensate local communities when industrial-country firms obtain patents on their indigenous knowledge (Box 2.6).

The rapid development of both science and intellectual property law presents the developing world with both opportunity and challenge. The opportunity is that the new technologies can be useful in developing products for tropical as well as for temperate zone diseases, and the expansion of the intellectual property system to developing countries will give the private sector greater incentive to develop these products. The challenge is that so many industrial-country firms are acquiring strong intellectual property positions, often covering fundamental research tools as well as marketable products, that it may prove hard for new firms and researchers to elbow into this new global industry. Developing-country firms and public research groups need to enter into agreements with industrial-country firms to obtain privately held technologies. And they need to understand how to negotiate these agreements and to participate in the continuing debate

Box 2.6

Providing local compensation when bioprospecting strikes gold

Madagascar's unique rose periwinkle plant was used to develop two anticancer drugs, vincristine and vinblastine, which together have generated more than $100 million in sales for a global pharmaceuticals company. Madagascar, however, got no financial return from these discoveries.

The example illustrates a growing concern, namely, that the strengthening of IPRs and their extension to biological materials will enable large multinationals engaged in bioprospecting to, in effect, appropriate valuable biomedical knowledge from indigenous peoples. Now, however, under pressure from nongovernmental organizations and environmental groups, large corporations are beginning to enter into contracts with local communities to provide compensation when the firm's innovations make use of the community's knowledge.

One of the best-known contracts is that negotiated between Merck & Company and INBio (Instituto Nacional de Biodiversidad), Costa Rica's nonprofit national biodiversity institute. Merck provided $1.1 million initially, plus a commitment to share royalties on any commercial products developed, in exchange for 2,000 to 10,000 extracts from plants, insects, and microorganisms in Costa Rica. INBio has now entered into nine research agreements giving companies limited access to biological resources in return for financial compensation and technology transfer.

about particular forms of intellectual property, to ensure that their interests and those of their country are taken into account.

The dawning of the digital era poses another set of problems. The merger of computer and telecommunications technologies has allowed the explosive growth of computer-mediated networks and the emergence of a global information infrastructure. In this new environment the frontiers between carriers and content providers become fuzzy. With a few keystrokes anyone can anonymously download copyrighted material from websites around the world. Prosecution of carriers who infringe on copyrights on digital information can discourage such infringement. But it may also inhibit the expansion of the value-added services that make the global information infrastructure so valuable.

In December 1996 WIPO convened a diplomatic conference to update the Berne Convention. The resulting WIPO Copyright Treaty and the WIPO Performance and Phonograms Treaty should facilitate the use of cyberspace for commercial applications by clarifying the rights of authors. For developing countries, joining these multilateral agreements can help advance the debate about reform in IPR laws to cope with the challenges of the digital age.

Stronger IPRs are a permanent feature of the new global economy, so it is important to find innovative ways of maintaining incentives to create knowledge while ensuring its broader diffusion. As Chapter 9 details, the initiatives in this direction range widely: from international public subsidies for research on technical knowledge of relevance for developing countries but not undertaken by the private sector, to partnerships between international organizations that want to see these technologies produced and the large private companies with the technical expertise to produce them.

Creating local knowledge

Developing countries cannot take advantage of the vast stock of global knowledge unless they develop the competence to search for appropriate technologies—and to select, absorb, and adapt what they find. The Overview showed that agricultural knowledge had to be adapted to local conditions for the green revolution to take hold. Even in manufacturing, knowledge produced in other countries often has to be adapted to differing conditions such as weather, consumer tastes, and the availability of complementary inputs. Making these adaptations often requires local research, which is also essential for following current developments in global knowledge and for selecting the most appropriate technology.

There is a strong complementarity between local technological efforts and technology imports. One recent study of technology institutions and policies gathered evidence from more than 2,750 firms in China, India, Japan, Korea, Mexico, and Taiwan, China. This study found, as did less extensive studies of Canada and Hungary, that firms with more in-house technical resources used more outside technological resources (such as those of technology institutions). It also found that the most important outside source of technology was long-term customers, followed by suppliers. Most of these customers and suppliers were foreign, confirming the importance of interaction through trade.

Similarly, firms with in-house R&D facilities were the most likely to receive technical assistance from customers in product and process innovations. This link seemed more valuable for firms catching up with international standards than for those already there. Foreign licensers were also very important sources for firms that had taken licenses, but licenses were considered costly both because of the high fees charged and the higher transactions costs. Consultants were also useful for firms that could afford the fees and transactions costs. Public technology institutes were very widely used, more by large companies than by small ones, because large companies could articulate their problems better.

Government-funded R&D

Since the private sector typically underinvests in R&D, governments have tried to encourage it either directly through public R&D or indirectly through incentives for private R&D. Direct government R&D includes that financed at universities, government research institutes, science parks, and research-oriented graduate schools. Indirect R&D interventions include preferential finance, tax concessions, matching grants, commercialization, and the promotion of national R&D projects. Developing countries spend a much smaller share of their GDP on R&D (an average of about 0.5 percent) than do the industrial countries (about 2.5 percent). And in the large majority of developing countries this R&D is funded by the government.

In most developing countries the allocation of public research funds to projects is haphazard, and fluctuations in research budgets undermine the continuity of projects, creating more inefficiency. But a few countries are strengthening research capacity, setting clearer research priorities, and establishing better systems for allocating public research funding on the basis of peer review. Some of the problems and reforms are well exemplified by Brazil, where the World Bank has been involved in a series of projects to strengthen capacity to produce, select, and adapt scientific and technological knowledge (Box 2.7).

Because adapting agricultural technology to local conditions is so important, and because the poorest developing economies are agriculturally based, most of their R&D is in agriculture, almost all of it publicly funded. As

Box 2.7

Changing the way Brazil does research

Brazil's scientific community is by far the largest in Latin America, yet the social and economic contribution from its research has been modest. The aims of a recent reform are to raise the standard of scientific and technological research to international levels, to improve the system for training high-level human resources, and to increase the relevance of the country's R&D for productive activity.

The Brazilian system exhibited all the flaws typical of developing-country research. Resources fluctuated dramatically with changing macroeconomic conditions, increasing the vulnerability of the system. Small grants of short duration, whose bureaucratic requirements lowered the productivity of researchers, were often awarded by administrators who lacked relevant expertise, not by scientific peers. Funds for equipment maintenance were scarce, import restrictions limited equipment availability, and inflation quickly eroded the value of grants. In addition, the system was strongly biased toward basic research, at the expense of applied work. Very little collaboration went on between researchers and firms. The system also lacked regional balance, with virtually all the world-class research being done in just a few of Brazil's southeastern states.

The Action Program for Science and Technology (known by its abbreviation in Portuguese, PADCT) grew out of the government's desire to equalize funding among disciplines in a system with a few dominant areas—notably physics—and many lagging ones. The World Bank helped develop two loans focusing broadly on reform of public funding for research, rather than on primarily rehabilitating select disciplines. The emphasis has been on appropriate "rules of the game" and on the long-term adoption of a transparent, merit-based system for allocating research resources.

Under the two loans, which totaled $479 million, 3,200 peer-reviewed research projects were awarded. A third loan, which was approved in 1997, will support a $360 million program to finance more than 1,000 projects in scientific research and technology development, with the emphasis on the latter.

Perhaps more important than the "how much," the PADCT has helped change "how" science is funded in Brazil. The peer review system of resource allocation has firmly established transparent, merit-based awarding of resources. And its rules have set a standard that other federal and state programs have adopted. The scientific community now does more in the way of planning and administration. Larger and longer-term grants are bringing Brazilian scientists closer to par with their colleagues in the industrial countries.

economies develop they increase their spending on R&D, but almost all of it continues to be publicly funded agricultural research. The average return to agricultural research has been around 60 percent, but the dispersion is high, reflecting the risks.

Unlike in much of industry, critical agricultural technologies (principally new seed varieties) are not well protected by IPRs, either globally or nationally. Therefore private investors do not provide enough R&D, especially for technologies applicable in the poorest countries, where information and market problems add to those of weak IPRs. The potential international spillovers that discourage private investors also enhance the economic effectiveness of international collective efforts in agricultural R&D, such as those undertaken through the system of international centers known as the Consultative Group for International Agricultural Research (see Chapter 9).

Only when developing countries come to have significant industrial sectors do they start to invest in industrial R&D, but for the most part even this continues to be publicly funded. Only as countries discover the need to upgrade their technology to compete in world markets does the private sector begin to invest in R&D.

Governments often lack information on the needs of the productive sector, and thus allocate funds for research inefficiently. As a result, many developing economies are reforming their public R&D institutes and making them more responsive to the market. Brazil, China, India, Korea, and Mexico have launched vast programs to reform public R&D laboratories and focus them on the needs of the productive sector. Reform measures include corporatizing these institutes, capping the government contribution to their budgets, improving researchers' pay and recognition, and giving firms direct incentives to place research contracts with the institutes.

China's reform program is a good example. With more than 1 million scientists and engineers and more than 5,000 research institutes, China has tremendous scientific and technological potential. With help from the World Bank the government is redirecting key assets of the country's large R&D infrastructure toward a results-oriented, market-based mode of operation that will increase productivity. Research laboratories and design institutions are being restructured and retooled to become true technology companies, some with the assistance of foreign investors or strategic partners. So far the government has invested in 47 engineering research centers, with 11 already operating as corporations. The balance sheet of each center has been sorted out, and each has a clear mandate from shareholders to innovate in the marketplace.

Private R&D

Private firms have taken a larger share of R&D in developing countries in the past 15 years. Basic scientific research is still done by highly qualified, specialized personnel—generally in academic institutions and public research laboratories, and mostly financed by government—while private research labs focus on applied R&D. The reason is simple: applied R&D, including engineering and product development efforts, leads to more directly appropriable results, whereas basic research, although it advances knowledge, usually does not. The public good features of basic research mean that usually only the government will provide it. In some cases, however, the cost of public R&D can be shared by private consortiums that benefit from commercialization. The private sector is also funding basic research in activities with potential for commercial applications, such as biotechnology.

Only a few developing economies—including Korea, Singapore, and Taiwan, China—have provided the right incentives for significant private R&D. Korea tops this list, with private R&D accounting for 2.3 percent of GDP (and 80 percent of the country's total R&D), one of the highest rates in the world. In 1975, when R&D spending was about 0.5 percent of GNP, and 80 percent of it public, the government launched a variety of incentives to promote private R&D. But what really spurred the increase was the need for more-advanced technology as the industrial sector matured in the 1980s. Acquiring this technology from abroad was becoming more difficult, so the private sector began to invest heavily in its own R&D to understand and acquire relevant technologies. As a result, Korea's publicly funded R&D institutes are redefining themselves, moving into more basic, precommercial research.

Building on local knowledge and local demand

For most developing countries, local research has to focus on more essential needs. And for local R&D to be relevant, particularly in agriculture and medicine, it should build on local knowledge, which can have tremendous value. In 1990 estimated world sales of medicines derived from plants discovered by indigenous peoples amounted to $43 billion. At least 25 percent of drugs prescribed in the United States use natural compounds derived from plants. For two-thirds of these the modern uses directly reflect the traditional applications.

In promoting local or adaptive research or in encouraging the adoption of modern technologies, care must be taken not to undermine useful traditional knowledge. Local technologies often require fewer material resources than imported technologies, allowing them to weather the vicissitudes of local shortages and material constraints. The oral rehydration solutions used to combat diarrhea provide an example. In some countries, aggressive promotions of subsidized, ready-made industrial packets undercut the use of long-known home remedies. When the subsidies ended and health education efforts stopped, the rate of use fell. But households that might have then reverted to traditional home remedies did not, because confidence in them had been undermined by the promotion of the commercial remedy. To avoid such an outcome in Nepal, oral rehydration programs preserved local knowledge by encouraging the use of homemade simple solutions alongside the modern packet solution (see Chapter 8).

Just as developing countries profit from knowledge from the industrial world, so do they benefit from preserving and deploying the knowledge developed in the course of their own history. But efforts to harness that knowledge, or to reconcile it with new technologies, require the involvement of those who possess it. And for the knowledge generated by local adaptive research to be relevant and broadly adopted requires full participation of end users and local communities in design and implementation. Local women in Colombia and Rwanda proved to know more about how to breed improved bean varieties locally than did scientists from the countries' research institutes (Box 2.8).

It is also important to take into account local constraints and the availability of complementary inputs. The promise of simple, improved biomass stoves has sparked a spate of stove programs in more than 41 countries, including China, Ethiopia, India, Kenya, and Rwanda, since the early 1980s. Domestic stoves that burn biomass fuels more efficiently offer large benefits to developing countries, where overuse of these fuels is depleting resources, degrading local

Box 2.8

Building a better bean: How women farmers in Colombia and Rwanda outdid the researchers

Scientists at the Institut des Sciences Agronomiques in Rwanda and at the Centro Internacional de Agricultura Tropical in Colombia collaborated with local women farmers to breed improved bean varieties. The two or three varieties considered by the breeders to have the most potential had achieved only modest increases in yields. The women farmers were invited to examine more than 20 bean varieties at the research stations and to take home and grow the two or three they thought most promising. They planted the new varieties using their own methods of experimentation.

Although the women's criteria were not confined to yield, the breeders' primary measure for ranking, their selections outperformed those of the bean breeders by 60 to 90 percent. The farmers were still cultivating their choices six months later.

environments, exacting time to collect fuel, and creating indoor pollution that harms the most vulnerable in the household: women and children. But only a few programs have prompted widespread adoption and use. At the heart of this shortcoming lies the early failure of program sponsors to focus design and marketing efforts on the demands and constraints of local consumers and manufacturers. Fortunately, that has changed (Box 2.9).

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To build their knowledge base, developing countries should explore all means of tapping the global stock of knowledge. Through their trade with the rest of the world, they can find new and better ways of producing goods and services. This is important as the structure of their trade shifts from primary to knowledge-intensive products. By attracting FDI, they can work with the global leaders in innovation, spurring all domestic producers to try to match their practice. But this will happen only with the right policies and appropriate infrastructure—for transport, for communications, for standards, indeed for doing business. Through licensing they can get access to new technology and can jump-start the accumulation of technological capital—if they negotiate to learn the underlying principles so that they can improve on what they are buying. And through the flow of people across borders, they can stay on top of the latest developments, often establishing lifelong relationships for the steady flow of know-how.

In all this, firms have to be encouraged to continue their search for the best techniques, to invest in training, and to upgrade their designs. Few things do more to encourage this than open, competitive markets—and few more to smother it than continuing subsidies. Also important is a balanced treatment of intellectual property that finds the right mix between providing incentives to create and acquire knowledge, and disseminating that knowledge at the lowest possible cost.

To take best advantage of the technology that comes in, and to spread successful practices throughout the economy, developing countries have to adapt that technology to local conditions. This should be the focus of government-funded R&D, initially in agriculture but increasingly in industry, as manufacturing develops. And increasingly the incentives should be put in place for private firms to take on their own R&D, initially in adapting, understanding, and refining the technologies they are already using, but eventually moving into research in those areas where they are close to international best practice.

The opportunities to be had from moving to better practices—from narrowing the knowledge gaps within and between countries—are nothing short of stupendous, and they apply not only to industry but across all sectors. Seizing those opportunities requires openness to outside ideas, the right incentives and institutions, and local effort dedicated to acquiring, adopting, and using knowledge effectively.

Box 2.9

Why better biomass stoves sold in Rwanda

The “Rondereza” charcoal stove was introduced in urban Rwanda in 1987, where high charcoal prices had created demand for more fuel-efficient stoves. Patterned on a popular Kenyan model, the Rondereza proved unpopular in early trials. What had worked in Kenya obviously did not work in Rwanda. The stove was then tested more extensively in 500 households and subsequently modified in terms of its size, valuation, quality, color, door design, and portability, in line with suggestions from householders and stovemakers.

Private entrepreneurs undertook (without subsidies) the production, distribution, and retailing of the stoves. This made the stove program oriented to consumers from the start. Government assistance, managed by a team of mostly Rwandan women, took the form of publicity campaigns, market surveys, training programs for stovemakers, and limited initial assistance for modernizing stovemaking equipment.

The program’s participatory, market-driven approach was quickly validated. Three years after its inception, 25 percent of urban households had the stove, which by then was widely available in market outlets and department stores. More than 90 percent of users surveyed indicated they would buy the stove again, citing not just its fuel economy but its cleanliness, long life, and ease of use. And the fuel savings achieved were on the order of 35 percent.