Developing Industrial Technology

Lessons for Policy and Practice

Farrokh Najmabadi
Sanjaya Lall

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A World Bank Operations Evaluation Study

Developing Industrial Technology

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Foreword

Technology plays a decisive role in how quickly and successfully a country industrializes. Enterprises need technical, managerial, and organizational skills to set up a plant, use it efficiently, improve and expand it over time, and develop new products and processes.

Through its project lending, the World Bank has always sought to help borrowers select suitable and cost-effective technologies and to operate industrial facilities efficiently. It was not until the 1980s, however, that the Bank began to focus systematically on the role that technological capability plays in economic development, and to analyze and advise on the types of policies, incentives, and organizational arrangements that might best promote this capability.

This study by the Bank's Operations Evaluation Department assesses how the Bank's lending for industrial technology has affected industry in six countries: India, Indonesia, Hungary, Korea, Mexico, and Spain. Based on experience with projects in contrasting economic settings, the study assesses the determinants of industrial technology development and the suitability of government policies.

Evaluation findings confirm the importance of incentives and of macroeconomic, trade, and industrial policies. In particular, judicious support by the public and private sectors is essential to stimulate research and innovation. Overall, the study emphasizes that efforts to build up capabilities for long-term industrial development need to address incentives, technological capabilities, and the role of institutions in a coherent way.

Robert Picciotto
Director General
Operations Evaluation

Prefacio

La tecnología es un factor decisivo para la rapidez y el éxito de la industrialización de un país. Al instalar, mejorar y ampliar una fábrica, y al desarrollar nuevos productos y procedimientos, las empresas deben contar con la necesaria capacidad técnica, administrativa e institucional.

A través del financiamiento para proyectos, el Banco Mundial ha procurado siempre colaborar con los prestatarios en la selección de tecnologías apropiadas y eficaces en función de los costos y en el manejo eficiente de las instalaciones industriales. No obstante, hasta la década de 1980 el Banco no había examinado sistemáticamente la importancia de la capacidad tecnológica como factor del desarrollo económico ni analizado ni asesorado sobre las políticas, incentivos y disposiciones institucionales que podrían estimular mejor esta capacidad.

En este estudio, realizado por el Departamento de Evaluación de Operaciones del Banco, se evalúa el efecto que han tenido los créditos del Banco para adquisición de tecnología industrial en la industria de seis países: España, Hungría, India, Indonesia, México y la República de Corea. Basándose en la experiencia adquirida a través de proyectos ejecutados en diferentes entornos económicos, el estudio examina los factores determinantes del progreso tecnológico industrial y la eficacia de las políticas gubernamentales.

Las conclusiones de esta evaluación confirman la importancia de los incentivos y las políticas macroeconómicas, comerciales e industriales. El apoyo responsable de los sectores público y privado, sobre todo, es fundamental para estimular la investigación y la innovación. En general, el estudio hace hincapié en que las medidas destinadas a fomentar la capacidad de desarrollo industrial a largo plazo deben ocuparse, en manera coherente, de los incentivos, la capacidad tecnológica y la labor de las instituciones.

Robert Picciotto
Director General
Evaluación de Operaciones

Préface

La technologie joue un rôle décisif dans la rapidité et la réussite de l'industrialisation d'un pays. Les entreprises ont besoin de compétences techniques, gestionnelles et organisationnelles pour établir une unité de production, l'exploiter efficacement, l'améliorer et l'agrandir progressivement, et mettre au point de nouveaux produits et procédés.

A travers ses prêts à l'investissement, la Banque mondiale a toujours cherché à aider les emprunteurs à choisir des technologies appropriées, présentant un bon rapport coût-efficacité, et à exploiter leurs installations industrielles de manière efficiente. Il a toutefois fallu attendre les années 80 pour que la Banque commence à se pencher systématiquement sur le rôle des capacités technologiques dans le développement économique, et à faire des analyses et émettre des avis sur les politiques, les mécanismes d'incitation et les modes d'organisation susceptibles de promouvoir ces capacités dans les meilleures conditions.

La présente étude, préparée par le Département de l'évaluation des opérations, évalue l'impact que les prêts de la Banque en faveur du développement technologique industriel ont eu sur le secteur industriel de six pays : la Corée, l'Espagne, la Hongrie, l'Inde, l'Indonésie et le Mexique. L'étude, qui s'appuie sur les enseignements tirés de projets réalisés dans des contextes économiques différents, cherche à évaluer les éléments qui déterminent le développement technologique industriel et à estimer l'adéquation des politiques menées par les pouvoirs publics.

Les conclusions de l'évaluation confirment l'importance des mécanismes d'incitation et des politiques macroéconomique, commerciale et industrielle. L'étude signale notamment que le concours judicieux des secteurs public et privé est indispensable pour stimuler la recherche et l'innovation. Globalement, elle confirme la nécessité d'adopter une démarche cohérente pour traiter des mécanismes d'incitation, des capacités technologiques et du rôle des institutions lorsqu'on s'emploie à renforcer les capacités pour le développement industriel à long terme.

Robert Picciotto
Directeur général
Evaluation des opérations

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Abbreviations and acronyms

BRITE/EURAM	Basic Research in Industrial Technologies in Europe/ European Research in Advanced Materials
CDTI	Centro para el Desarrollo Tecnologico Industrial (Spain)
CENAM	Centro Nacional de Meteologia (Mexico)
CMEA	Council of Mutual Economic Assistance
COCOM	Coordinating Committee for Multilateral Exports
CONACYT	Consejo Nacional de Ciencia y Tecnología (Mexico)
EC	European Community
EEC	European Economic Community
ERP	Effective rate of protection
ESPIRIT	European Strategic Programme for Research and Development in Advanced Information
EUREKA	European Project for Cooperation in Market Oriented R&D
FDI	Foreign direct investment
FONEI	Fondo de Equipamiento Industrial (Mexico)
GDP	Gross domestic product
GNP	Gross national product
ICICI	Industrial Credit and Investment Corporation of India
INI	Instituto Nacional de Industria (Spain)
IRDE	Industrial research, development, and engineering
ITD	Industrial technology development
KIET	Korea Institute of Economics and Technology
KTDC	Korea Technology Development Corporation
KTIC	Korea Technology Investment Corporation
LPND	Nonministerial government institute (Indonesia)
NAFINSA	Nacional Financiers SA (Mexico)
NCL	National Chemical Laboratory (India)
NIC	Newly industrialized country
NIE	Newly industrialized economy
OECD	Organization for Economic Cooperation and Development
OED	Operations Evaluation Department
PE	Public enterprise
R&D	Research and development

RD&E	Research, development, and engineering
SAR	Staff appraisal report
S&T	Science and technology
SECOFI	Secretary of Commerce and Industrial Development (Mexico)
SMEs	Small- and medium-scale enterprises
SMIs	Small and medium industries
SPP	Mexican Secretariat of Planning and Budget
TC	Technological capability
TDF	Technology Development Fund (India)
TFP	Total factor productivity
TI	Technology import
UNESCO	United Nations Educational, Scientific and Cultural Organization
VCF	Venture capital fund

Executive summary

Introduction

The Bank has played an important role, through its project lending, in enhancing borrowers' technological capabilities. It has helped borrowers to select appropriate and cost-effective technologies and to efficiently operate industrial facilities. This process has often contributed to the development of a capability on the part of borrowers for implementing similar projects. But throughout the early days and until the 1970s, technological capability building remained incidental to the Bank's major lending activities.

By the mid-1970s, the Bank also began to take account of the role of technology in industrial development. After the establishment of the office of Science and Technology Advisor, a number of studies were conducted for the promotion of scientific and technological capabilities in the developing countries. The Bank also looked at the existing situation in a few developing countries: one of the earliest reports was prepared for Indonesia in 1972 ("Problems of Industrial Technology"). The Bank's first lending for industrial technology development was approved in 1975 for Israel. This was a component of the Industrial Development Loan (1116-IS). The Bank's first complete project for industrial technology development was launched in 1977 in Spain.

It was, however, during the 1980s that the issue of industrial technology development began to receive systematic attention in the Bank. A comparative study of technology development in four countries was undertaken. Technological issues were addressed in the industrial sector studies of the larger newly industrialized economies (NIEs). In addition to projects with strong technology components, a series of technology development projects, again mostly for NIEs, was designed and approved. But such efforts remained sparse and, despite the inclusion of technology development in the Bank's industrial lending, general awareness of the importance of developing technological capability did not go beyond the Bank's staff directly involved in the subject.

Objectives of the study

The primary objective of this study is to assess the impact that the Bank's lending for industrial technology development has had on the industrial sector of the borrowing countries. In particular, the study attempts to assess the Bank's view of the determinants of industrial technology development and the policies that it recommended. The study also addresses project achievements, the appropriateness of project objectives to the given circumstances, and the factors that contributed to their success or failure.

This study focuses on industrial technology development projects in six countries: Hungary, India, Indonesia, Korea, Mexico, and Spain. These are not the only countries in which the Bank has undertaken technology development (or closely related) projects, but the choice was intended to reflect different types of projects and different economic settings. India, Indonesia, and Korea represent Asian countries at varying stages of industrialization and pursuing different trade and industrial strategies. Mexico was chosen as a major Latin American country with a sizable and diverse industrial sector that has recently undergone sweeping liberalization. Spain was the location of the Bank's earlier efforts; its location and stage of development have evident points of interest. Hungary is the only East European country to have a technology loan from the Bank, and the only country in that region that abolished central planning a long time ago.

An analytical framework

Much of technological effort in developing countries is directed at the acquisition of technological capabilities (TCs). TCs in industry are the skills—technical, managerial, and organizational—that are necessary for enterprises to set up a plant, utilize it efficiently, improve and expand it over time, and develop new products and processes. Industrial technology development (ITD) refers to the growth of these technological capabilities. ITD is a necessary and integral part of efficient industrialization at all levels of development.

In most developing countries ITD means the ability to become more efficient and competitive in the use of imported technologies. In the least-developed countries ITD comprises the mastery of simple and well-diffused technologies, while in the NIEs it involves mastering complex, scale- and skill-intensive technologies. Over time, ITD also involves "deepening" of TCs, that is, the undertaking of more complex and demanding tasks (adaptation, improvement, design, engineering, development, and innovation) within the technologies that the country utilizes. The process of technological deepening has various benefits and generates various externalities. It can lead to more widespread diffusion of technology, greater use of local inputs, more product differentiation, higher added value, and the ability to respond more effectively to changes in market conditions.

The capabilities needed to deploy efficiently a new manufacturing facility are generally not present in most developing countries. Nor are these capabilities easily transferred from abroad as part of the sale of equipment, patents, or blueprints. There are "tacit" elements in the transfer of all but the simplest technologies that call for indigenous skill creation, learning, and the collection of new information, only parts of which occur as a passive process of learning by doing. The process requires conscious and sustained effort on the part of the manufacturer, and is costly and uncertain. Moreover, the successful mastery of operational technology (know-how) may not automatically lead to the development of deeper technological capabilities (know-why). A strategic decision generally has to be made to invest in the more risky and prolonged process of gaining the extra knowledge and skills required.

ITD is determined by the interplay of incentives, capabilities, and institutions. The *incentive framework* gives the "demand" for technological effort. Apart from the basic need to get into production, incentives for technological effort arise from the macroeconomic environment and growth prospects, technological progress, factor markets, the intellectual property regime, and domestic and foreign competition. Of these, competition (especially world competition) is generally the most potent stimulus to ITD. Where competition has been restricted, as in highly protected trade regimes, liberalization may be a necessary condition for the development of competitive TCs. However, because the process of capability development involves time, risk, and investment, there is a period during which the enterprise is less efficient than one that has already undergone the learning process. Thus, in the period of infancy, a cushion may be needed in order to promote technological learning.

While infant industry protection can provide the breathing space in which new entrants can develop their capabilities, there are many potential dangers in such interventions, arising from the risk of government failure. The recent history of import-substituting industrialization in developing countries is replete with interventions that were poorly designed and badly implemented. Protection can itself retard or distort investments in ITD, especially if domestic competition is weak and the protection is granted in a widespread and indiscriminate manner. To ensure that infant industries invest in ITD, therefore, safeguards have to be instituted. The most effective safeguards are those that introduce market competition at the earliest possible time, such as immediate promotion of domestic competition, early entry into export markets, and time-bound programs of protection. Successful ITD requires, on the part of the government, a clear strategic objective, administrative skills, flexibility, careful monitoring, and the correction or penalization of poor performance.

Capabilities and institutions determine the "supply side" of ITD. While the final capability building takes place inside the manufacturing firms, firms have to depend on external sources for inputs that they cannot create easily. The three major building blocks to which firms need recourse are skills of the appropriate kinds, financing for physical and capability investment, and access to information and technology to feed into in-house efforts. Each of these has its own markets. Each may suffer from market failures, and there may be a need for governments to ensure that the supply of skills, finance, and information necessary for ITD is adequate.

In particular, access to foreign technology is a critical determinant of ITD. Such access provides one of the most economical ways of gaining the initial input of a new technology. If accompanied by skills, training, and other assistance, it also reduces the tasks that the recipient has to do to master and keep up with the technology. Restricting such access can raise the cost of ITD enormously, or can retard the process to the extent that local efforts cannot substitute for foreign ones. There are, however, many ways to access foreign technologies, with different effects on local ITD. The correct allocation of resources between creating technology at home and buying it abroad is a complex matter, and overreliance on either may be costly or inefficient. Passive dependence on foreign technology may lead to good operational capabilities, but may not necessarily be the best way to deepen local capabilities. Foreign technology should be an input into local efforts and not entirely a substitute for it. After a certain level, dynamic and sustained industrial development always involves some deepening of domestic capabilities to take on design, development, and innovative work. Otherwise the highest value-added segments of industry remain out of reach.

In the broadest sense, institutions provide the "rules of the game" within which enterprises operate and enter into contracts in the markets for factors and products. This framework should be transparent, stable, and predictable, and should not discriminate between industrial actors according to origin, ownership, or size. Institutions in the narrower sense refer to the organizations set up to support the functioning of the skill, capital, and information markets that are relevant to ITD. The main ones are education and training institutes, development finance and venture-capital institutions, science and technology institutions, and others that support subcontracting, small-scale enterprises, and information flows. Institution building is widely accepted as essential to development in all its forms, and is a critical part of the promotion of ITD.

The technology problem in the sample countries

The issues in industrial technology differed enormously across the six sample countries. There were a number of common problems that all these countries faced because of the practically universal nature of market failures in the provision of finance, skills, and information to industrial firms investing in technological activity. However, the weight and incidence of the specific market failures differed. More importantly, the incentive frameworks within which firms were investing in ITD varied greatly, as did the "traditions" that countries had developed over time of investing in local innovative effort as opposed to buying more difficult technologies from the advanced countries. These traditions, themselves the outcome of location, history, and past policy interventions, appear to exert an independent influence on ITD, regardless of the impact of incentives arising from the trade and industrial regimes.

Spain's large and long-established industrial structure had improved its operational capabilities considerably over a period of gradual liberalization and active policies to restructure firms and raise linkages with the science and technology (S&T) infrastructure. However, it showed technological immaturity in its weak research and development (R&D) performance and its relatively (in the context of the European Community) poor showing in dynamic areas of manufacturing activity. This resulted from a weak technological tradition, which may have been compounded by inadequate ITD financing and insufficient infrastructure support.

Korea built up a deep and diverse industrial structure by virtue of deliberate interventions in the trade and industrial regime, guiding the allocation of industrial investments in particular directions largely under the control of national private firms. These firms imported technology mainly in the form of equipment and licenses, relying relatively little on direct foreign investments. This raised the technological challenge for them significantly, especially because of the pressures on them to be export-oriented very quickly after entering production. As industries entered more complex activities and approached the frontiers of their technologies, local R&D became imperative to keep abreast of world levels of competitiveness.

The skill requirements of this effort in Korea were met by massive investments in higher level technical education and by measures to induce firm-level training. Finance requirements were initially left to the existing financial intermediaries, supplemented by a number of instruments to support R&D in approved projects by the *chaebol* (conglomerates). Smaller innovators and other forms of technological effort were not addressed. The S&T infrastructure received a lot of financial and human resources, and seemed to succeed in establishing good linkages with industry. These measures led to spectacular increases in private R&D and an attitude to undertake technological activities that enabled Korea to achieve its main industrial ambitions. The main gaps that existed were in remedying the financial market failures for smaller innovators and helping the research infrastructure to enter more areas of activity to promote the government's industrial strategy. These were the aims of the Bank's main efforts in the technology area.

Indonesia had a much simpler industrial structure than the other countries in the sample, and so had correspondingly simple technological needs. It started with strong protection and inward bias; this has been improved, but significant and haphazard protection still exists and the pace of liberalization is unclear. Indonesian industry remains highly import-dependent for components and equipment as well as for technology and skills, and local firms invest practically nothing in engineering, design, and development. However, some firms are showing increasing mastery of complex process industries as liberalization forces them to invest more in technological learning and operational efficiency. The skill base is small, and the lack of an industrial and research tradition exacerbates the low output of high-level technical manpower. The only concerted technological effort comes from a few "strategic industries" that are entering high-technology activities unrelated to the bulk of private industrial activity. The S&T infrastructure is weak and delinked, except for a part that serves the strategic industries. The financing of ITD is nonexistent. Thus, Indonesia's ITD problems cover a wide range, from incentives to skills, finance, information support, and linkage between S&T and industry.

Mexico combines a long history of import substitution with a tradition of heavy reliance on imported technology. This strategy was quite successful in creating efficient process and automotive industries, but remained deficient in fostering equipment production. Few local enterprises developed a tradition of design and development over time, and even public enterprises showed a strong preference for imported equipment and know-how. Local industrial R&D is the lowest of any major industrializing country, and this remains true in a period of rapid liberalization. The skill base is reasonably good. There is large S&T infrastructure that has suffered the usual lack of linkages with production. The financing of technology activity, though addressed by policymakers, has been weak. The basic problems of Mexican ITD have been the reluctance of firms to invest in deepening their own capabilities and entering the design and development process, and the gaps in the S&T infrastructure.

Hungary's ITD problems in the past decade were primarily related to the incentive framework and the system of ownership, governance, and trade. Despite its substantial and deep industrial base and long tradition of R&D, its hesitant and partial reforms had failed to utilize its technological activity and experience fully to make industry competitive in Western markets. There were also other problems. The base of high-level technical skills was weaker than in western European countries. The S&T infrastructure was comprehensive, but had become outdated and underfunded. Nevertheless, some firms retained an autonomous technological tradition and capabilities. At that time, the incentive, governance, and control system was the basic constraint on ITD, with minor ones arising in the financial and infrastructure support areas.

India developed its industrial base behind a set of interventions that had mixed effects, with the costs of inefficiency and technological lags apparently outweighing the benefits of deepening. It pursued a strategy of technological self-reliance more assiduously than most other countries, and invested in a large S&T infrastructure. A broad base of technological capabilities was developed, and there was significant growth of R&D activity. However, the skill base for industry remained relatively small, and distortions in the incentive system meant that technological learning did not lead to fully competitive production or to innovative capabilities. The S&T infrastructure was largely delinked from production. Access to foreign technologies was restricted. ITD finance was not well developed. The technological needs of small- and medium-sized firms were not addressed, while R&D by the large-scale private sector was inadequate. A large and generally inefficient public sector engaged in some research, but only a few public enterprises achieved competitive capabilities.

Thus, India's technological problems were wide-ranging, covering all aspects of incentives, capabilities, and institutions.

The technology projects

The underlying objective of all the ITD projects was to strengthen the competitiveness and productivity of the industrial sector. This was based on two general premises, articulated in most of the project documents. The first is that some technological capabilities are essential to achieving world levels of efficiency at all levels of industrial development, but that as the industrial structure grows more complex a developing country has to deepen its capabilities. In particular, it has to invest in design and development capabilities to absorb and build upon more advanced imported technologies. The second is that there are market failures in the acquisition of technological capabilities, which have to be addressed by policy instruments.

The ITD projects showed a keen awareness of the importance of the incentive framework for promoting the "demand" for technological activity. Given the nature of the projects, they did not address directly incentive issues related to macroeconomic, trade, and industrial policies. However, in all the countries in which these projects were launched a certain degree of liberalization was under way, and it was expected that this would promote the demand for ITD. The projects therefore focused on market failures on the "supply side."

As far as skill needs were concerned, only one country, Indonesia, was regarded as having the shortage of technical skills as the primary constraint to technological activity. The others were considered to have ample technical skills within enterprises and institutions, though some training was envisaged in most other projects for financial, appraisal, and management skills.

On capital-market failures, practically all the projects with the exception of Indonesia emphasized the need for finance for technological activity. The Korea project had venture capital and other new technology financing instruments as its exclusive focus. The Hungarian, Indian, Mexican, and Spanish projects had technology finance as a major focus, along with efforts to remedy failures in information markets. The aims of the finance component differed across countries. The Spain project was to finance the import, development, and diffusion of selected technologies as part of a specific strategy of changing the country's technology culture. The Hungary project was primarily to provide loans for the import of up-to-date equipment and technologies from the West for process control and software. The India project was to finance local innovative efforts via venture capital as well as the import of technology, while the Mexico and Korea projects were to finance both the absorption of foreign technology and the commercialization of local technologies.

The strengthening of the information and technical services network generally involved two objectives: improving the capabilities of S&T institutions, and establishing closer linkages between them and industry. The strengthening of institutions was a major objective in three of the projects (four if the skill development for the nonministerial government institutes in Indonesia is included). In India, the project fed into the government's broader market-oriented reforms of the technology infrastructure. In Mexico, the project linked investment in selected research institutes to their partial privatization. In Hungary, the project included strengthening the metrology and quality control centers, and the augmenting of infrastructure provision of inputs into R&D. The need to improve research institutes and industry linkages was mentioned in most projects, though in Hungary and Indonesia they did not appear as immediate objectives.

An assessment

The need for ITD is clearly and forcefully stated in nearly all the project documents. In general, it is argued that the need to make existing industries competitive and to develop new sources of comparative advantage in manufacturing both need investments in technology development. The perception is that technological activity is a driving force in industrial development, productivity, and competitiveness in developing countries; it is a purposive activity that does not result automatically from a passive learning process, and requires enterprises to invest in specific areas like training, information collection, engineering, design, and experimentation; it involves the interaction between individual enterprises and an infrastructure of science and technology institutions that provide certain services with "public goods" characteristics; and there is a need to deepen technological capabilities with industrial development.

The project documents accept that operational capabilities may not be easy to acquire, and may need policy support. At the same time, they suggest that technological deepening may not follow automatically from the development of operational capabilities. They recognized that the need for technological deepening grows with industrial development. The lack of advanced capabilities holds back, not just the ability of local firms to diversify, diffuse technology, and reap the externalities that arise from technological activity, but also their ability to absorb more sophisticated technologies from abroad. R&D serves as much to keep up with technical progress as to generate innovations. In general, the technology projects' analysis of ITD needs is based on sound premises. This does not mean that technological deepening of this nature should be of immediate concern to many developing countries or that the NIEs need necessarily enter into R&D activities in all the most advanced technologies. It does, however, mean that in the process of industrial development choices may have to be constantly made to enter certain more sophisticated and complex areas of technology. Otherwise the highest value-added segments of industry may remain out of reach.

On the determinants of ITD, there is a clear awareness that the *incentive framework* has a critical impact on the extent and nature of TC investments, and that the framework has to be conducive to industrial development as a whole. The Bank's decision to undertake ITD projects, and their specific design, depends strongly on its reading of the incentive regime in each country. This is entirely justified: long-term investments in capability development and R&D are bound to be exceptionally sensitive to incentives arising from the macroeconomic and competitive environment, which determine the "demand" for ITD.

While the precise incentive requirements of ITD are not discussed explicitly in the project documents, it is possible from their analysis and from other Bank writing on industrialization to decipher the Bank's view of the desirable incentive framework for capability development. It is one that meets the following four conditions: First, it provides a liberal trade regime, with considerable exposure over time to international competition in all its forms (import as well as export competition). The case for protecting particular activities to promote ITD is generally more than counterbalanced by the risk of government failure in exercising selectivity. Second, it provides full access to foreign technology and equipment in all its forms. Third, it promotes domestic competition fully, removing all artificial constraints to entry and exit. Fourth, it emphasizes the role of the private sector.

This is based on the Bank's experience of industrial development in a range of countries pursuing a variety of strategies. On both theoretical and practical grounds, the four criteria noted below have much to recommend them. ITD is strongly driven by international competition. Technology imports are a necessary input into local capability development, and attempts to inflict technological self-reliance are generally disastrous for healthy ITD. Selectivity does not have a good record, and picking technological winners is especially difficult. Domestic competition is conducive to ITD and to efficiency and growth. Finally, the private sector is generally more efficient and responsive to market signals than the public.

On the issue of the relationship between trade strategy and ITD, there remains a valid case for infant industry protection. New entrants to industry face extra costs because they have to undergo a technological learning process that has already been gone through elsewhere. The case for interventions rests on the existence of market failures in this learning process: externalities (skills and knowledge leak out to other firms); complementarities in ITD development across vertically related firms (learning in one firm affects the competitiveness of another, but neither firm takes this into account in its own investment decisions); firms themselves are unaware of, or unable to predict properly, the benefits arising from ITD investments; or, finally, firms are extremely risk averse and discount the future at a socially undesirable rate. Experience shows, however, that the interventions are best located in a strongly export-oriented regime that offsets the disincentive effects of infant industry protection while providing the competition and information benefits of participating in world trade. The need for protection, moreover, declines as ITD progresses. With the progress of technological learning, industries have to be exposed to import competition to stimulate further ITD—but the exposure should not be so sudden that the learning process itself is aborted.

The immediate policy problem confronting the Bank and the developing world today are less to do with the promotion of infant industries than with the restructuring of existing industries set up under distorted incentive frameworks. Here too the issues of promoting technological learning surface, but in a different guise. For economies with a number of industries that have attained maturity (or near maturity) under protectionist trade regimes, immediate liberalization is necessary to allow them to exploit their existing comparative advantages in world markets. However, for industries that are potentially competitive, there may be a case for phased programs of restructuring and relearning. The entry of new and complex activities may still need to be supported through appropriate trade policies. The case for such trade policies to promote ITD appears to be underplayed in the technology project documents.

The Bank's industrial technology lending has had varying impacts in the sample countries. In Korea the three loans contributed to promoting R&D activities in small- and medium-scale enterprises that needed risk capital to sustain such activities. In India, too, the project is proceeding well and has assisted the private-sector industrial enterprises in acquiring technology from abroad, the innovators to have access to venture-capital funds, and a number of research and development institutes to direct their efforts towards the needs of industry. In Spain, the project was, to a degree, instrumental in encouraging and promoting efforts to develop new processes and products, and to bring them to the point of commercialization, though the entry into the European Economic Community in 1986 and the exposure to the Community R&D activities has, in recent years, really pushed the Spanish industry in the direction of increased efforts.

The impact of the Bank's lending in the other three countries is less encouraging. While the Indonesia project achieved its limited objective of enlarging the skill base by sending Indonesian graduates abroad for obtaining higher degrees, it is unlikely to enhance the technological capabilities of Indonesian industry in the broad sense. The Mexico project failed to achieve its major objectives of promoting real R&D activities in the private sector and the privatization of research institutes. It succeeded, however, in bringing about the formulation of a new technology policy as a result of a study supported by the project. In Hungary, except for the National Office of Measures (metrology), which has used the Bank loan for the import of valuable measuring instruments, many of the other beneficiaries are facing serious problems because their markets have changed radically.

The provision of technology financing was one of the major objectives of Bank ITD projects (except in Indonesia) and aimed at removing one of the main constraints to technology development. The particular attention that the projects paid to the need of small- and medium-sale enterprises (SMEs) was welcome in that these enterprises face greater financial constraints than large enterprises. The purposes for which technology finance was provided included the development of local technologies as well as the absorption and adaptation of imported technologies.

The strengthening of infrastructure institutions and their links to industry was a legitimate concern of ITD projects. The projects adopted different approaches to this end. Projects in India and Mexico attempted to improve both the functioning of the R&D infrastructure as well as their linkage with industry. In Korea and Spain, too, the projects aimed at strengthening research institute-industry linkages, while the Indonesian project had the training of researchers for its institutes as the main objective.

The Bank's objectives on the "supply side" issues of factor market failures were generally sound. Clearly capital-market failures can affect ITD, especially by medium-sized enterprises, and poor or inadequate infrastructural support can inhibit the flow of information and the undertaking of certain forms of technological effort and R&D. All measures to remedy these inadequacies can be helpful to technological activity. However, their benefits may be narrower than the projects originally envisaged. They may result in improving operational capabilities rather than promoting more demanding levels of technological activity. *If the habit to undertake R&D is weak, it is not clear that concentrating on these supply side measures would suffice to stimulate deeper ITD.* These issues needed greater attention in some of the technology projects.

Moreover, there was insufficient attempt in some projects to tailor the design to the history and industrial traditions of the country. There was perhaps a belief that the underlying process of ITD was uniform across countries, and that all countries would adopt this process once the incentive structure was liberalized and the capital- and information-market failures overcome. In general, the design of the projects was well suited to country conditions in India and Korea. The Indonesia project suffered from serious flaws in the design, given the objective of improving skills that would benefit the technological capabilities of Indonesian industry in the broad sense. The Mexico project had an interesting design for the privatization of research institutes, but left some important questions unanswered as to the implementation and utility of creating this sort of linkage. The removal of financial constraints to ITD in the Mexican and Spanish projects was correctly designed for stimulating the kind of technological activity that already existed in those countries, but not for enabling a significant jump in ITD.

Lessons learned and recommendations

Based on the experience from the industrial technology projects in the sample countries the following factors may be cited as those most instrumental in the outcome of the projects. ITD should form a part of a broader strategy for industrialization; otherwise its impact may be diluted. There is need for an integrated approach in the preparation of ITD projects where incentives, technological capabilities, and institutions are all discussed and addressed simultaneously.

The impact of a technology project on ITD depends on the existence of a clearly defined and articulated technology strategy. The projects in Korea were effective because the Korean government not only had a strong hand in directing the economic and especially the industrial development of Korea, it also formulated a clear strategy for the technological development. This was the case, to a lesser extent, in many of the other countries, and where there was need the Bank insisted on a technology policy study to be carried out.

Since the industrial technology projects usually address issues of the factor market failures on the "supply side," it should be reiterated that the incentive framework is a crucial determinant of ITD. In addition to a sound macroeconomic setting, liberal trade, industrial, and technology policies play a decisive role in promoting ITD. Where the incentive regime is highly distorted—as in Hungary at the time of the project's inception—even well designed measures on the supply side do not lead to a dynamic process of ITD. Industrial technology development projects should, therefore, not be implemented until the economic environment is conducive to their potential success.

Access to foreign technologies is critical to ITD, and the Indian case study illustrates the damage that may result from widespread and severe restrictions on technology imports. However, the mode of technology import may affect the extent and nature of local capability development. A heavy reliance on foreign direct investment can be an extremely effective method of transferring operational know-how of new technologies, and can have numerous beneficial externalities. It may not, however, be the best way to promote technological deepening. In Korea, the preference for arm's length technology imports over direct investment encouraged local enterprises to invest in their R&D capabilities, because it was complemented by a battery of policies encouraging industry to enter complex areas while forcing them to face export competitions.

The deepening of industrial technology capability may also need interventions in trade and technology regimes that promote local research activity. Exposure to international competition and technology flows by itself may not—as witnessed in Mexico and Spain—be sufficient for the promotion of technological effort. The Bank should examine its understanding of what drives the process of technological development and the creation of an R&D culture, paying particular attention to the effects of imported technology inputs versus local technology development.

Technological dynamism requires a heavy involvement on the part of the private sector in technological activities. The role of public institutions in technology should decline over time to provide support for private technological activities. Very few countries have managed this transition. In the case of Korea, this involved, in addition to clear trade, industrial, and science and technology strategies, several financial and fiscal measures to encourage private-sector R&D. Conversely, in Mexico formal technological activity was very low, and nearly all of it was in public institutions. Given the nature of R&D activities, government policy should encourage private R&D through incentives including fiscal and other measures.

Technological effort is necessary for efficient industrialization at all levels. Though the

Bank's ITD projects have so far been mainly concentrated on NIEs, they should be started in less industrialized countries. In some developing countries, what may be initially required to promote competitiveness and efficiency are the improvement in skills and an efficient technology infrastructure (for standards, metrology, quality assurance, and so on) before elaborate R&D facilities are created.

Long-term trends in technology affect competitiveness and technological response of each country. Although the Bank cannot specialize in all such technologies, it, nevertheless, needs to have some idea of the critical areas of generic technologies on which developing countries may need guidance. This would give more meaning to its industrial technology development lending activities.

There is need for the dissemination of ITD literature within the Bank and a serious discussion of the subject. ITD projects are currently carried out by a few individuals in the Bank who understand the imperatives of technology development but often find it difficult to communicate their concerns to others. This is all the more important because of the Bank's preoccupation with the supply response and competitiveness that is expected from trade and industrial policy reform and industrial restructuring.

Project implications

In financing R&D by firms, the Bank should look for intermediaries that understand R&D, have technical expertise, are knowledgeable about various industries, and are committed and willing to take risks. The ownership of the project should, therefore, be vested in only dynamic organizations that are willing to lead, facilitate, and monitor progress in the interest of efficiency. Normal financial intermediaries like commercial banks are generally not equipped to deal with the needs of such financing, and it is desirable to entrust such activities to specialized financial institutions.

Successful financing of technological innovation in industry depends on the institutional make-up of the financial intermediary. Though the government's presence may be necessary to get started, the intermediary should have strong private-sector participation and support as well as complete autonomy so that bureaucratic interventions are avoided. The Indian and Korean experiences illustrate the advantages of privately managed institutions that are responsive to market needs and have intimate relationships with industry. Conversely, in Mexico the first tier commercial banks had very little inputs in the technology loans.

Successful technology and venture-capital financing depends, to a very large extent, on the experience and quality of the staff of the institutions. Not only should the institution attract and retain qualified staff, it should continue to improve their effectiveness through a variety of training programs.

Venture-capital and risk-sharing operations should be approached with great care because the skills required to manage them are not always readily available and take time to develop. In the Indian project, the projections made on the uptake of such financing was overoptimistic. Risk-sharing activities also require the availability of financial resources that permit prudent risk-taking. In setting up the financing of the intermediaries, there is need for reasonable certainty as to the sources of finance, the commitments by the government in terms of assistance, and well designed devolution program.

In all the countries in the present study, R&D institutions set up to deal with industrial technologies have found it difficult to link up with manufacturing enterprises. The privatization of public research institutes faces various difficulties, as illustrated by the experience in Mexico where enterprises were reluctant to take on the ownership and management of such institutes. Since large firms normally have their own resources for R&D, priority should be given to financing R&D for SMEs. Financial incentives to the private sector might help create linkages between SME and R&D institutes.

While it is important to have the private sector represented in the policymaking bodies of public R&D institutes, it is highly unlikely that the private R&D institutions can be put in place through the collective participation of private-sector firms without strong government support and financial assistance. The services of the private-sector private institutions could be brought in to facilitate the linkage between industry and R&D institutes.

The best approach towards strengthening research linkages seems to be one where it is clearly recognized: (a) that only those research institutes with the "service to industry" culture could be instrumental in strengthening the linkage; and (b) that firms, especially SMEs, face *serious information and credibility gaps* in subcontracting research to institutes. This is partly a problem of their inability to define clearly their own technological needs. It is partly due to a lack of knowledge on their part of the capabilities of the institutes and a lack of trust on industrial secrecy. These gaps can be filled best by subsidizing, at least at the start, the process of linkage creation, while securing some financial commitment on the part of the enterprises. Many of the ITD projects did recognize the need for this subsidization, and it took the form of conditional loans, preferential interest rates, targeting selected activities, and so on. This approach was correct, though a systematic assessment of the form of support that works best is still lacking.

Resumen

Introducción

A través de sus préstamos para proyectos, el Banco ha desempeñado una importante función para potenciar la capacidad tecnológica de los prestatarios, lo que ha permitido a éstos escoger tecnologías apropiadas y eficaces en función de los costos, y explotar de forma eficiente las instalaciones industriales. Con frecuencia, este proceso ha contribuido a desarrollar la capacidad de los propios prestamistas para poner en práctica proyectos similares. Sin embargo, en los primeros tiempos y hasta la década de los años setenta, el fortalecimiento de la capacidad tecnológica era un elemento accesorio en las principales operaciones de préstamo del Banco.

A mediados de la década de los setenta, el Banco comenzó a tomar en consideración también el papel de la tecnología en el desarrollo industrial. Tras la creación de la Oficina del Asesor, ciencia y tecnología, se realizaron varios estudios para fomentar la capacidad científica y tecnológica en los países en desarrollo. El Banco también analizó la situación de unos pocos países en desarrollo: uno de los primeros informes fue el que se preparó sobre Indonesia en 1972, titulado "Problems of Industrial Technology". El primer préstamo del Banco para el desarrollo de tecnología industrial se aprobó en 1975 a favor de Israel, y fue un componente del Préstamo para el Desarrollo Industrial (1116-IS). El primer proyecto para el desarrollo de la tecnología industrial se realizó en España en 1977.

Sin embargo, fue durante los años ochenta cuando el Banco comenzó a prestar una atención sistemática al desarrollo de la tecnología industrial. En esa época se llevó a cabo un estudio comparativo del desarrollo tecnológico en cuatro países. Las cuestiones tecnológicas se abordaron en los estudios de los sectores industriales de las economías de reciente industrialización (ERI) más grandes. Además de los proyectos que incluían importantes componentes tecnológicos, se elaboró y aprobó una serie de proyectos de desarrollo tecnológico, destinados también en su mayoría a las ERI. No obstante, todos estos esfuerzos resultaron insuficientes y, pese a la inclusión del desarrollo de la tecnología en los préstamos industriales del Banco, puede decirse que sólo los funcionarios de la institución que participaban directamente en los proyectos eran plenamente conscientes de la importancia del desarrollo de la capacidad tecnológica.

Objetivos del estudio

El objetivo principal del presente estudio es evaluar el impacto que han tenido en el sector industrial de los países prestatarios los préstamos para el desarrollo de la tecnología industrial otorgados por el Banco. Concretamente, uno de los objetivos del estudio es evaluar la forma en que el Banco ha considerado los determinantes del desarrollo de la tecnología industrial y las medidas de política que ha recomendado aplicar. También se analizan en el estudio los éxitos obtenidos en la ejecución de los proyectos, la idoneidad de los objetivos de dichos proyectos conforme a las circunstancias, y los factores que contribuyeron al éxito o al fracaso de los mismos.

El estudio se centra en los proyectos de desarrollo de la tecnología industrial en seis países: Corea, España, Hungría, India, Indonesia y México. Estos países no son los únicos en los que el Banco ha emprendido proyectos de desarrollo tecnológico (y proyectos estrechamente relacionados), pero se han elegido estos seis países precisamente como ejemplos de distintos tipos de proyectos y diferentes situaciones económicas. Corea, India y Indonesia son países asiáticos en diversas etapas de industrialización y con estrategias comerciales e industriales distintas. México se eligió por ser uno de los principales países latinoamericanos con un sector industrial grande y diversificado que ha registrado recientemente una liberalización generalizada. España fue el primer país en que el Banco emprendió uno de los primeros proyectos en este campo: su situación geográfica y su grado de desarrollo son características especialmente interesantes. Hungría es el único país de Europa oriental que ha recibido un préstamo del Banco para el desarrollo de la tecnología y el único país de la región que abolió la planificación centralizada hace mucho tiempo.

Marco analítico

Gran parte del esfuerzo desplegado en los países en desarrollo en materia de tecnología se orienta a la adquisición de capacidad tecnológica. En el sector industrial, este tipo de capacidad son los conocimientos —de carácter técnico, gerencial y organizativo— que necesitan las empresas para poner en marcha instalaciones, utilizarlas eficientemente, mejorarlas y ampliarlas con el tiempo, y crear nuevos productos y procesos. El desarrollo de la tecnología industrial (DTI) se refiere al perfeccionamiento de esa capacidad tecnológica. El DTI es un componente necesario de toda política eficiente de industrialización, cualquiera que sea el nivel de desarrollo.

En la mayoría de los países en desarrollo, el DTI se refiere a la capacidad para ser más eficientes y competitivos en el uso de la tecnología importada. En los países menos adelantados, el DTI consiste en dominar tecnologías sencillas y de amplia difusión, mientras que en las ERI conlleva el dominio de tecnologías complejas, tecnologías de escala y tecnologías que requieran un uso intensivo de conocimientos. Con el tiempo, el DTI entraña también el "perfeccionamiento" de la capacidad tecnológica, es decir, la realización de actividades más complejas y difíciles (adaptación, mejora, diseño, ingeniería, desarrollo e innovación) en el marco de las tecnologías que utiliza el país. Este proceso de perfeccionamiento aporta diversos beneficios y genera varias externalidades. Puede dar lugar a una difusión más amplia de la tecnología, un uso más intenso de los insumos locales, una mayor diferenciación de los productos, un aumento del valor agregado y la capacidad para reaccionar en forma más eficaz cuando varíen las condiciones del mercado.

La capacidad necesaria para poner en marcha con eficiencia una nueva planta manufacturera no suele darse en general en la mayoría de los países en desarrollo. Tampoco puede transferirse fácilmente desde el extranjero como si fuera un componente más de las ventas de equipo, patentes o planos. En la transferencia de todas las tecnologías, salvo las más simples, hay elementos "tácitos" que requieren capacitación, aprendizaje y adquisición de nueva información en el propio país; de todos estos elementos, sólo algunos se adquieren en un proceso pasivo de aprendizaje sobre la marcha. El proceso exige un esfuerzo consciente y constante por parte del fabricante y resulta costoso e incierto. Además, el dominio completo de la tecnología operativa (el "saber cómo") no supone necesariamente el desarrollo automático de conocimientos tecnológicos más avanzados (el "saber por qué"). En general, para invertir en un proceso más arriesgado y más largo como el que conlleva la adquisición de los conocimientos teóricos y prácticos adicionales necesarios, hay que adoptar una decisión estratégica.

El DTI viene determinado por la interacción de incentivos, capacidad e instituciones. La *estructura de incentivos* crea la "demanda" de esfuerzo tecnológico. Aparte de la necesidad básica de iniciar la producción, los incentivos que estimulan el esfuerzo tecnológico tienen su origen en el entorno macroeconómico y en las perspectivas de crecimiento, en el progreso tecnológico, los mercados de factores, el régimen de propiedad intelectual y la competencia nacional y extranjera. De todos ellos, la competencia (especialmente la competencia mundial) suele ser el estímulo más poderoso para el DTI. En los casos en que se ha limitado la competencia, como ocurre en los regímenes comerciales muy protegidos, la liberalización puede ser una condición necesaria para el desarrollo de capacidad tecnológica competitiva. Sin embargo, como este proceso conlleva tiempo, riesgo e inversión, hay un período en que la empresa es menos eficiente que otra que haya superado ya el proceso de aprendizaje. Así pues, en la fase incipiente quizá sea necesario algún tipo de protección para estimular el aprendizaje de la tecnología.

Si bien la protección de la industria naciente puede dar un respiro a las nuevas empresas para que desarrollen su capacidad, este tipo de intervenciones entraña también muchos peligros potenciales que tienen su origen en el riesgo de un fracaso del gobierno. La experiencia reciente de los países en desarrollo, con respecto a la industrialización basada en la sustitución de las importaciones, está repleta de intervenciones mal diseñadas y ejecutadas. La protección puede de por sí retrasar o distorsionar las inversiones en DTI, sobre todo si la competencia interna es deficiente y la protección se otorga de forma generalizada e indiscriminada. Por lo tanto, para que las industrias nacientes inviertan en DTI hay que establecer ciertas salvaguardias. Las más eficaces son las que introducen la competencia de mercado en la fase más temprana posible, como la inmediata promoción de la competencia interna, el pronto acceso a los mercados de exportación y los programas de protección por tiempo limitado. Para que el DTI tenga éxito se requiere por parte de las autoridades la fijación de un objetivo estratégico claro, además de capacidad administrativa, flexibilidad, una política de seguimiento minucioso y la corrección o la penalización de todo desempeño deficiente.

La *capacidad y las instituciones* son factores que determinan el "lado de la oferta" del DTI. Si bien el fortalecimiento definitivo de la capacidad se produce dentro de las empresas manufactureras, éstas se ven obligadas a depender de recursos externos para obtener los insumos que no pueden crear fácilmente. Los tres pilares más importantes a los que las empresas han de tener acceso son conocimientos apropiados, financiamiento para inversión física y en perfeccionamiento, además de acceso a la información y a la tecnología para estimular la capacitación en la empresa. Cada uno de estos pilares tiene sus propios mercados, cada uno es susceptible de sufrir fallos en los respectivos mercados; por eso quizá sea necesario que las autoridades tomen las medidas necesarias para que la oferta de conocimientos prácticos, financiamiento e información necesarios sea la adecuada.

Concretamente, el acceso a la tecnología extranjera es un determinante crucial del DTI. Dicho acceso constituye uno de los medios más económicos para adquirir lo que puede aportar desde el principio una nueva tecnología. Si se complementa con conocimientos prácticos, capacitación y otro tipo de asistencia, facilita además al beneficiario el esfuerzo que tiene que desplegar para dominar la tecnología y mantenerse al día. Limitar ese acceso puede elevar enormemente el costo del DTI o puede retrasar el proceso en la medida en que no existan insumos nacionales que puedan sustituir a los extranjeros. No obstante, hay muchas formas de acceso a la tecnología extranjera, que producen efectos distintos en el DTI nacional. La correcta asignación de los recursos entre el desarrollo de la tecnología en el país y su adquisición en el exterior es un tema difícil, y si se hace excesivo hincapié en una u otra opción, el proceso puede resultar costoso o ineficiente. La dependencia pasiva de la tecnología extranjera puede servir para alcanzar un buen nivel de conocimientos operativos, pero no es necesariamente la mejor forma de desarrollar la capacidad local. La tecnología extranjera debe ser un insumo que refuerce la capacidad nacional y no algo que la reemplace totalmente. Una vez que se alcanza determinado nivel, para que el desarrollo industrial sea dinámico y sostenido, siempre es necesario ampliar la capacidad nacional, de suerte que puedan asumirse funciones de diseño, desarrollo e innovación. De lo contrario, los segmentos de la industria con valor agregado más alto quedan fuera del alcance.

En el sentido más amplio, las instituciones proporcionan las "reglas de juego", es decir un marco en el que las empresas operen y suscriban contratos en los mercados de factores y de productos. Este marco debe ser transparente, estable y previsible, y no debe ser discriminatorio para ninguno de los agentes por razón de origen, propiedad o magnitud. Las instituciones, en el sentido más estricto del término, son los organismos establecidos para apoyar el funcionamiento de los mercados de conocimientos, capital e información, pertinentes a efectos del DTI. Las más importantes son las instituciones de enseñanza y capacitación, las de desarrollo financiero y capital de riesgo, las instituciones científicas y tecnológicas y otros organismos que respaldan la subcontratación, la pequeña empresa y los flujos de información. El fortalecimiento institucional es una actividad que generalmente se considera esencial para el desarrollo en todas sus formas y es un componente crucial para fomentar el DTI.

El problema de la tecnología en los países estudiados

La tecnología industrial presenta aspectos muy diferentes en los seis países estudiados. Todos ellos tenían una serie de problemas comunes, debido al carácter prácticamente universal de las deficiencias del mercado con respecto a la provisión de financiamiento, conocimientos técnicos e información a las empresas industriales que invierten en tecnología. Sin embargo, la magnitud y la incidencia de las distintas deficiencias variaban de unos países a otros. Lo que es más importante, la estructura de incentivos en la que se enmarcaban las inversiones de las empresas, también variaba mucho, al igual que las "tradiciones" que los países habían desarrollado con el tiempo, en el sentido de invertir en innovaciones nacionales en vez de adquirir tecnologías más complicadas de los países adelantados. Estas tradiciones, que también son resultado de la situación geográfica y de la historia, así como de las intervenciones en materia de política económica, parecen influir de forma independiente sobre el DTI, al margen del impacto que puedan tener los incentivos del régimen comercial e industrial.

España, con una estructura industrial grande y sólidamente establecida había mejorado considerablemente su capacidad operativa durante un período de progresiva liberalización y de aplicación de medidas activas para reestructurar las empresas y reforzar los vínculos con la infraestructura científica y tecnológica. Sin embargo, el país tenía algunas carencias tecnológicas que se manifestaron en áreas como la investigación y el desarrollo y en los resultados relativamente deficientes (en comparación con otros países de la Comunidad Europea) de algunos aspectos dinámicos de la industria manufacturera, como consecuencia de una tradición tecnológica deficiente; además, la insuficiencia de financiamiento para actividades de DTI y la falta de infraestructura pueden haber agravado el problema.

Corea fue desarrollando una estructura industrial sólida y diversificada a través de intervenciones deliberadas en el régimen comercial e industrial, orientando la inversión industrial hacia actividades concretas, generalmente bajo el control de empresas privadas nacionales. Estas empresas importaron tecnología, sobre todo en forma de equipo y licencias, dependiendo relativamente poco de la inversión extranjera directa. En estas circunstancias, tuvieron que hacer frente a un desafío tecnológico mucho mayor, sobre todo por las presiones que sufrieron para orientar rápidamente sus actividades hacia la exportación una vez iniciado el proceso de producción. A medida que las industrias empezaron a desarrollar actividades más complejas y se aproximaban al límite de su capacidad tecnológica, la investigación y el desarrollo a escala nacional se convirtieron en un factor imprescindible para mantenerse al nivel de la competencia mundial.

En el caso de Corea, para satisfacer las exigencias en materia de conocimientos técnicos se invirtió masivamente en educación de nivel técnico superior y se tomaron medidas para fomentar la capacitación dentro de las empresas. Las necesidades de financiamiento se dejaron en un principio en manos de los intermediarios financieros existentes, cuyos recursos se complementaron con una serie de instrumentos de apoyo a la investigación y el desarrollo en proyectos aprobados por el *chaebol*. No se consideró la situación de los pequeños innovadores ni otras formas de desarrollo tecnológico. La infraestructura científica y tecnológica recibió un gran volumen de recursos financieros y humanos, y al parecer se logró establecer buenas relaciones con la industria. Todas estas medidas se tradujeron en un espectacular aumento de las actividades de investigación y desarrollo de carácter privado y en una actitud muy positiva para realizar actividades tecnológicas que permitieron al país alcanzar sus principales objetivos industriales. Las deficiencias más notables se observaron en la corrección de las imperfecciones del mercado financiero con respecto a los pequeños innovadores y en la forma de ayudar a que la infraestructura de investigación participara en más áreas de actividad para fomentar la estrategia industrial de las autoridades. Estos eran los principales objetivos que persiguió el Banco en materia de tecnología.

La estructura industrial de Indonesia era mucho más sencilla que la de los demás países estudiados y, por lo tanto, sus necesidades de tecnología eran también menores. La situación de partida fue de fuerte protección con un sesgo autárquico; pese a que se han producido mejoras, el nivel de protección sigue siendo elevado y arbitrario, y el ritmo de la liberalización no está claro. La industria de Indonesia sigue dependiendo mucho de las importaciones de componentes y equipo, así como de tecnología y conocimientos prácticos, y las empresas nacionales no invierten prácticamente nada en ingeniería, diseño y desarrollo. Sin embargo, algunas empresas están demostrando un dominio cada vez mayor de industrias con procesos complejos en la medida en que la liberalización les está obligando a invertir más en aprendizaje tecnológico y eficiencia operativa. La base de conocimientos prácticos es pequeña, y la falta de una tradición industrial y de investigación agrava el problema del bajo rendimiento de una mano de obra técnica de alto nivel. El único esfuerzo concertado en el campo de la tecnología proviene de unas pocas "industrias estratégicas" que están realizando actividades de alta tecnología independientes del grueso de la actividad industrial privada. La infraestructura científica y tecnológica es deficiente y poco coordinada, salvo un sector que atiende a las industrias estratégicas. No hay financiamiento para el DTI; por consiguiente, el país sufre toda una serie de problemas a este respecto, problemas que afectan tanto a los incentivos como a los conocimientos prácticos, el financiamiento, la información y las relaciones de la infraestructura científica y tecnológica con la industria.

México combina una larga trayectoria de sustitución de las importaciones con una tradición de fuerte dependencia de la tecnología importada. Esta estrategia tuvo mucho éxito en la industria automotriz y en las industrias de procesamiento, pero no bastó para estimular la producción de equipo. Pocas empresas nacionales forjaron una tradición de diseño y desarrollo a lo largo del tiempo, e incluso las empresas públicas manifestaron una acusada preferencia por el equipo y la tecnología de importación. Los niveles de investigación y desarrollo industriales son los más bajos de todos los grandes países en vías de industrialización, incluso en un período de rápida liberalización. La base de conocimientos prácticos es razonablemente sólida. Existe además una amplia infraestructura científica y tecnológica que ha padecido la habitual falta de conexión con la producción. El financiamiento de la actividad tecnológica, aunque ha sido abordado por las autoridades encargadas de formular la política económica, ha sido escaso. Los problemas básicos del DTI en el caso de México han sido la renuencia de las empresas a invertir para ampliar su propia capacidad e incorporarse al proceso de diseño y desarrollo, y las deficiencias en la infraestructura científica y tecnológica.

En Hungría, los problemas de DTI en los diez últimos años guardaron relación básicamente con el sistema de incentivos y con el sistema de propiedad, gobierno y comercio exterior. Pese a la sólida y desarrollada base industrial y a la larga tradición de investigación y desarrollo, las reformas, vacilantes y parciales, no han servido para aprovechar al máximo la actividad y la experiencia tecnológicas del país a fin de hacer su industria más competitiva en los mercados occidentales. También hay que señalar otros problemas: la base de conocimientos técnicos de alto nivel no era tan sólida como en los países de Europa occidental; la infraestructura científica y tecnológica era muy completa, pero se había quedado obsoleta y carecía de respaldo financiero. No obstante, algunas empresas conservaron una tradición y una capacidad tecnológicas autónomas. Al mismo tiempo, el sistema de incentivos, gobierno y control constituía la limitación básica del DTI, además de algunas otras de menor importancia en materia de respaldo financiero e infraestructura.

India desarrolló su base industrial en el marco de una serie de intervenciones que tuvieron resultados desiguales; en este sentido, los costos de la ineficiencia y los desfases tecnológicos sobrepasaron al parecer las ventajas del desarrollo. El país aplicó una estrategia de autosuficiencia tecnológica con más perseverancia que la mayoría de los demás países, e invirtió en una gran infraestructura científica y tecnológica. Se creó una base diversificada de conocimientos tecnológicos y se produjo un significativo aumento de las actividades de investigación y desarrollo. Sin embargo, la base de conocimientos prácticos en la industria siguió siendo relativamente pequeña y las distorsiones del sistema de incentivos significaron que el aprendizaje tecnológico no sirvió para que la producción fuese totalmente competitiva, ni para desarrollar la capacidad de innovación. La infraestructura científica y tecnológica estaba desvinculada en gran medida de la producción; el acceso a las tecnologías extranjeras estaba limitado; el financiamiento del DTI no estaba suficientemente desarrollado. Tampoco se estaba dando cobertura a las necesidades de la pequeña y mediana empresa, en tanto que las actividades de investigación y desarrollo del sector privado de gran escala eran insuficientes.

El sector público, de grandes dimensiones y en general ineficiente, participó algo en la investigación, pero sólo unas pocas empresas públicas adquirieron un nivel competitivo de capacidad. En resumen, los problemas tecnológicos del país eran muy variados y afectaban a todos los aspectos del sistema de incentivos, a la capacidad y a las instituciones.

Los proyectos de tecnología

El objetivo básico de todos los proyectos de DTI era reforzar la competencia y la productividad del sector industrial basándose en dos premisas generales enunciadas en la mayoría de los documentos relativos con los proyectos. La primera es que para alcanzar niveles de eficiencia internacionales en todos los aspectos del desarrollo industrial, se necesita cierta capacidad tecnológica, pero que a medida que la estructura industrial se hace más compleja, los países en desarrollo tienen que ampliar esa capacidad. Concretamente, tienen que invertir en diseño y desarrollo para asimilar tecnologías de importación más adelantadas y cimentar en ellas los conocimientos. La segunda es que, al adquirir capacidad tecnológica se producen imperfecciones en los mercados, que deben resolverse utilizando instrumentos de política.

En los proyectos de DTI se tenía muy presente la importancia de la estructura de incentivos para estimular la "demanda" de actividades tecnológicas. Los proyectos, habida cuenta de su carácter, no abordan directamente la cuestión de los incentivos relacionados con las políticas macroeconómicas, comerciales e industriales. Sin embargo, en todos los países en los que se pusieron en marcha este tipo de proyectos, ya existía cierto grado de liberalización, y se estimaba que así se fomentaría la demanda de DTI. Por lo tanto, los proyectos se centraron en las imperfecciones del mercado por "el lado de la oferta".

En lo que respecta a las necesidades de conocimientos, puede decirse que sólo en un país, Indonesia, la principal limitación de la actividad tecnológica tenía su origen en la falta de conocimientos técnicos. En los demás países se consideró que los conocimientos técnicos de las empresas e instituciones eran suficientes, aunque en la mayoría de los demás proyectos se contempló la posibilidad de ofrecer capacitación para desarrollar los conocimientos financieros, gerenciales y de evaluación.

Con respecto a las imperfecciones de los mercados de capital, prácticamente todos los proyectos, salvo el de Indonesia, hacían hincapié en la necesidad de financiamiento para la actividad tecnológica. En el caso de Corea, la atención se enfocó exclusivamente en el capital de riesgo y en otros nuevos instrumentos de financiación de la tecnología. En los proyectos desarrollados en España, Hungría, India y México, el financiamiento de la tecnología era uno de los principales objetivos, junto con algunas medidas para corregir las imperfecciones de los mercados de información. Los objetivos que perseguía el componente de financiamiento eran distintos en cada país. En España, se trataba de financiar la importación, el desarrollo y la difusión de determinadas tecnologías como parte de una estrategia concreta para modificar la cultura tecnológica del país. En Hungría, el proyecto tenía por objeto sobre todo proporcionar préstamos para la importación de Occidente de equipos y tecnologías modernos para el control de procesos industriales y programas de informática. En India, el proyecto tenía por objeto financiar la innovación local por medio de capital de riesgo e importación de tecnología, mientras que en México y Corea el objetivo de los proyectos era financiar la asimilación de tecnología extranjera y la comercialización de las tecnologías locales.

En general, para fortalecer la red de información y servicios técnicos había que alcanzar dos objetivos: mejorar la capacidad de las instituciones científicas y tecnológicas, y estrechar los vínculos entre estas instituciones y la industria. El fortalecimiento institucional fue uno de los objetivos principales en tres de los proyectos (cuatro, si se incluye el perfeccionamiento de los conocimientos de las instituciones públicas no ministeriales de Indonesia). En India, el proyecto se enmarcó en un programa más amplio elaborado por las autoridades para reformar la infraestructura tecnológica conforme a criterios de mercado. En el proyecto de México, se vinculó la inversión en algunos centros de investigación con la privatización parcial de los mismos. En Hungría, se fortalecieron los centros de metrología y control de calidad, y se aumentó la provisión de insumos de infraestructura para investigación y desarrollo. La necesidad de fortalecer los centros de investigación y las relaciones con la industria se mencionó en la mayoría de los proyectos, aunque en el caso de Hungría e Indonesia no figuraron como objetivos inmediatos.

Evaluación

En casi todos los documentos relativos a los proyectos se hace claramente hincapié en la necesidad de DTI. En general, se argumenta que para aumentar la competitividad de las industrias y desarrollar nuevas ventajas comparativas en la industria manufacturera es necesario invertir en investigación y desarrollo. Se considera que la actividad tecnológica es una fuerza impulsora del desarrollo industrial, la productividad y la competitividad en los países en desarrollo; es una actividad intencional que no se genera automáticamente en un proceso pasivo de aprendizaje y que requiere que las empresas inviertan en temas específicos como la capacitación, la recopilación de información, la ingeniería, el diseño y la experimentación, una actividad que entraña la interacción de las empresas a escala individual y de una infraestructura de instituciones científicas y tecnológicas que presten ciertos servicios con características de "bien público", y es necesario perfeccionar la capacidad tecnológica con desarrollo industrial.

En los documentos relativos a los proyectos se acepta que la capacidad operativa puede no ser fácil de adquirir y que quizá necesite el respaldo de ciertas medidas de política. Al mismo tiempo, se indica que el desarrollo de la capacidad operativa no necesariamente se traduce de forma automática en un perfeccionamiento tecnológico. Se reconoce que la necesidad de perfeccionamiento tecnológico aumenta con el desarrollo industrial. La falta de conocimientos avanzados retrasa no sólo la capacidad de las empresas locales para diversificarse, difundir la tecnología y aprovechar las externalidades que produce la actividad tecnológica, sino también su capacidad para asimilar tecnología de vanguardia procedente del extranjero. La investigación y el desarrollo sirven tanto para mantenerse al día de los progresos técnicos como para generar innovaciones. En general, el análisis de las necesidades de DTI en los proyectos de tecnología se basa en premisas sólidas. Esto no significa que muchos países en desarrollo deban preocuparse por un perfeccionamiento tecnológico de esta naturaleza, ni que las ERI tengan que participar necesariamente en actividades de investigación y desarrollo en todas las tecnologías más avanzadas. Lo que sí significa, sin embargo, es que en el proceso de desarrollo industrial hay que estar decidiendo constantemente si se participa o no en campos más sofisticados y complejos de la tecnología. De lo contrario, los segmentos de la industria con mayor valor agregado pueden quedar fuera del alcance.

En cuanto a los determinantes del DTI, está muy claro que la *estructura de incentivos* repercute de forma crucial en el alcance y la naturaleza de las inversiones en capacidad tecnológica, y que dicha estructura ha de fomentar el desarrollo industrial en su conjunto. La decisión del Banco de emprender proyectos de DTI, y su diseño específico, depende mucho de la interpretación del régimen de incentivos de cada país, lo cual está totalmente justificado: las inversiones a largo plazo en perfeccionamiento de la capacidad e investigación y desarrollo son extraordinariamente sensibles a los incentivos del entorno macroeconómico y competitivo, que determinan la "demanda" de DTI.

Si bien los incentivos concretos que requiere el DTI no se examinan explícitamente en los documentos relativos a los proyectos, analizando dichos documentos y otros estudios del Banco sobre industrialización es posible descifrar qué estructura de incentivos considera conveniente la institución para desarrollar la capacidad. Esta estructura debe satisfacer cuatro condiciones: primera, facilitar un régimen comercial liberal, con un alto grado de apertura a lo largo del tiempo a la competencia externa en todas sus formas (con respecto tanto a la importación como a la exportación). El riesgo de que las autoridades no adopten un enfoque selectivo contrarresta con creces las ventajas de proteger ciertas actividades para fomentar el DTI. Segunda, brindar un acceso total a la tecnología y al equipo extranjeros en todas sus formas. Tercera, estimular al máximo la competencia interna eliminando todos los obstáculos artificiales que limitan la entrada y salida. Cuarta, hacer hincapié en el papel del sector privado.

Todo esto se basa en la experiencia del Banco en materia de desarrollo industrial en una serie de países que aplican toda una gama de estrategias. Por motivos teóricos y prácticos, las cuatro condiciones mencionadas son muy recomendables. La competencia internacional impulsa con fuerza el DTI. Las importaciones de tecnología son un insumo necesario para el desarrollo de la capacidad local, y todos los intentos por imponer un nivel de autonomía tecnológica suelen ser desastrosos para el sano desarrollo del DTI. La adopción de un enfoque selectivo no ha producido buenos resultados y, en el terreno de la tecnología, es muy difícil prever quién va a ganar. La competencia interna favorece el DTI, así como la eficiencia y el crecimiento. Por último, el sector privado en general es más eficiente y reacciona mejor a las señales del mercado que el sector público.

Con respecto a la relación entre la estrategia comercial y el DTI, sigue siendo válido proteger las industrias incipientes. Las empresas que participan por primera vez en un sector incurren en costos extraordinarios porque tienen que pasar por un proceso de aprendizaje tecnológico que otras empresas ya han superado. La conveniencia de las intervenciones se basa en que existen imperfecciones del mercado en este proceso de aprendizaje: externalidades (filtración de conocimientos prácticos y teóricos a otras empresas), complementariedades en el desarrollo del DTI entre empresas con una estructura vertical de relaciones (el aprendizaje en una empresa afecta a la competitividad de otra, pero ninguna de las dos lo tiene en cuenta en sus propias decisiones de inversión); las propias empresas no son conscientes de las ventajas que reporta la inversión en DTI, o no pueden preverlas adecuadamente; por último, puede ocurrir que las empresas sean sumamente reacias a asumir riesgos e hipotequen el futuro a un costo social indeseable. La experiencia ha demostrado, sin embargo, que las intervenciones son más eficaces en un *régimen muy orientado a la exportación* que compense los efectos negativos de desincentivo que produce la protección de la industria naciente, manteniendo al mismo tiempo las ventajas que, en materia de competencia e información, conlleva la participación en el comercio internacional. Además, a medida que avanza el DTI, la protección se hace menos necesaria. Con el avance del aprendizaje tecnológico, las industrias tienen que abrirse a la competencia de las importaciones para estimular aún más el DTI, pero la apertura no debe ser tan brusca que haga fracasar el propio proceso de aprendizaje.

El problema más inmediato en materia de políticas que enfrentan hoy día el Banco y los países en desarrollo no es tanto la promoción de las industrias nacientes como la reestructuración de las ya existentes, creadas en un marco de incentivos distorsionado. También en este caso surgen problemas relativos a la promoción del aprendizaje tecnológico, pero de manera distinta. En las economías con algunas industrias que han alcanzado ya su madurez (o están a punto de hacerlo) bajo un régimen comercial proteccionista, la liberalización inmediata es necesaria para que puedan explotar las ventajas comparativas que ya tienen en los mercados mundiales. Sin embargo, en el caso de las industrias que podrían ser competitivas, estaría justificada la adopción de programas graduales de reestructuración y readiestramiento. Quizá haya que seguir apoyando con las medidas comerciales adecuadas la incorporación de actividades nuevas y complejas. No parece que en los documentos relativos a los proyectos se haya dado la importancia que merece a la posibilidad de aplicar este tipo de políticas comerciales para fomentar el DTI.

Los préstamos otorgados por el Banco para el desarrollo de la tecnología industrial tuvieron repercusiones diversas en los países estudiados. En Corea, los tres préstamos contribuyeron a estimular la investigación y el desarrollo en empresas pequeñas y medianas que necesitaban capital de riesgo para mantener esas actividades. También en India, el proyecto va por buen camino y ha brindado asistencia a las empresas industriales del sector privado para adquirir tecnología del extranjero, y ha permitido a los innovadores tener acceso a capital de riesgo, y a algunos centros de investigación y desarrollo encauzar sus esfuerzos hacia las necesidades de la industria. En España, el proyecto fue hasta cierto punto decisivo para estimular y fomentar el desarrollo de nuevos procesos y productos, y llevarlos al punto de comercialización, aunque la incorporación a la CEE en 1986 y el contacto con las actividades de investigación y desarrollo de la Comunidad es lo que realmente ha impulsado el mayor esfuerzo que ha realizado la industria española en los últimos años.

El impacto de los préstamos del Banco en los otros tres países es menos alentador. Si bien en Indonesia se alcanzó el objetivo limitado de ampliar la base de conocimientos enviando a titulados universitarios al extranjero para ampliar sus estudios, es improbable que el proyecto aumente la capacidad tecnológica de la industria nacional en general. En el caso de México, no se logró alcanzar los principales objetivos: fomentar las auténticas actividades de investigación y desarrollo del sector privado y privatizar los centros de investigación. Sí se logró, sin embargo, formular una nueva política tecnológica como resultado de un estudio realizado en el marco del proyecto. En Hungría, salvo la Oficina Nacional de Medidas (metrología) que ha utilizado el préstamo del Banco para la importación de valiosos instrumentos de medición, muchos de los demás beneficiarios sufren graves problemas porque sus mercados han cambiado radicalmente.

Uno de los principales objetivos del Banco en materia de DTI era otorgar financiamiento para tecnología (salvo en el caso de Indonesia), procurando eliminar una de las principales limitaciones al desarrollo tecnológico. La especial importancia que en los proyectos se prestaba a las necesidades de la pequeña y mediana empresa fue algo positivo, ya que dichas empresas sufren restricciones financieras más severas que las empresas grandes. El financiamiento en materia de tecnología se otorgó para desarrollar la tecnología local y asimilar y adaptar la tecnología importada.

En los proyectos de DTI se consideró que el fortalecimiento de las instituciones de infraestructura y de sus vínculos con la industria era un objetivo legítimo. Para alcanzar dicho objetivo, se adoptaron diversas estrategias en los proyectos. En India y México, en los proyectos se procuró mejorar tanto el funcionamiento de la infraestructura de investigación y desarrollo como sus vínculos con la industria. En Corea y España, los proyectos también se orientaron a fortalecer los vínculos entre los centros de investigación y la industria, mientras que en Indonesia, el proyecto estableció como principal objetivo la capacitación de los investigadores para los centros del país.

En general, los objetivos del Banco con respecto a las imperfecciones de los mercados de factores, vistas desde "el lado de la oferta", eran acertados. Está claro que las imperfecciones del mercado de capitales pueden afectar al DTI, sobre todo en el caso de las empresas medianas, y si el respaldo en materia de infraestructura es deficiente o inadecuado, pueden verse limitados el flujo de información, y determinados proyectos tecnológicos, así como las actividades de investigación y desarrollo. Todas las medidas que se adopten para corregir estas deficiencias pueden contribuir a la actividad tecnológica. Sin embargo, los beneficios que se obtengan pueden ser menores que los contemplados originalmente en los proyectos. Más que fomentar actividades tecnológicas de mayor nivel, estas medidas pueden mejorar la capacidad operativa. *Si no hay costumbre de realizar actividades de investigación y desarrollo, aún está por verse si concentrar la atención en este tipo de medidas por el "lado de la oferta" bastaría para estimular el perfeccionamiento del DTI.* En algunos de los proyectos de tecnología no se prestó suficiente atención a estas cuestiones.

Además, en algunos proyectos no se hizo lo suficiente por adaptar el diseño a la historia y las tradiciones industriales del país. Se creía quizás que el proceso básico de DTI era uniforme en todos los países, y que todos ellos adoptarían este proceso una vez liberalizada la estructura de incentivos y corregidas las imperfecciones de los mercados de capitales y de información. En Corea y India, en general, se adaptó bien el diseño de los programas a las condiciones del país. En el caso de Indonesia hubo graves fallas en el diseño, dado que el objetivo establecido era mejorar los conocimientos prácticos que habrían potenciado la capacidad tecnológica de la industria del país en términos generales. El proyecto de México tenía un buen diseño para la privatización de los centros de investigación, pero dejaba sin respuesta cuestiones importantes con respecto a la implantación y la utilidad de crear este tipo de vínculo. La eliminación de las limitaciones financieras para el DTI en los proyectos de España y México se diseñó acertadamente para estimular el tipo de actividad tecnológica que ya existía en esos países, pero no para dar un impulso significativo al DTI.

Enseñanzas y recomendaciones

La experiencia acumulada en la ejecución de los proyectos de tecnología industrial en los países estudiados permite destacar los siguientes factores como los más fundamentales para lograr los objetivos previstos.

El DTI debe enmarcarse en una estrategia de industrialización más amplia; de lo contrario su impacto puede ser menor. Al formular los proyectos de DTI, debe adoptarse un enfoque integrado en el que se aborden y estudien al mismo tiempo los incentivos, la capacidad tecnológica y las instituciones.

El impacto de un proyecto de tecnología sobre el DTI depende de que se defina y formule claramente una estrategia tecnológica. Los proyectos de Corea fueron eficaces porque las autoridades no sólo dirigieron con firmeza el desarrollo económico, y sobre todo el desarrollo industrial, sino porque además formularon una estrategia inequívoca con respecto al desarrollo tecnológico. Es lo que ha sucedido también, aunque en menor medida, en muchos de los otros países y, en caso necesario, el Banco ha insistido en que se realicen estudios de la política tecnológica.

Como en los proyectos de tecnología industrial generalmente se aborda el tema de las imperfecciones de los mercados de factores desde "el lado de la oferta", debe hacerse hincapié en que la estructura de incentivos es un determinante crucial del DTI. Además de un marco macroeconómico propicio, una política comercial, industrial y tecnológica de carácter liberal desempeña un papel decisivo a la hora de fomentar el DTI. Cuando el régimen de incentivos está muy distorsionado —como en el caso de Hungría al iniciarse el proyecto— por muy bien diseñadas que estén las medidas por el lado de la oferta no se produce un proceso dinámico de DTI. Por lo tanto, los proyectos de desarrollo de tecnología industrial no deben ponerse en marcha hasta que el entorno económico sea propicio para que tengan éxito.

El acceso a la tecnología extranjera es fundamental para el DTI, y el caso de India es un buen ejemplo de los daños que puede ocasionar la imposición generalizada de severas restricciones a las importaciones de tecnología. Sin embargo, la forma en que se importe la tecnología puede afectar al alcance y a la naturaleza del desarrollo de la capacidad local. Una fuerte dependencia de la inversión extranjera directa puede ser un medio sumamente eficaz para transferir el conocimiento operativo de nuevas tecnologías, y puede producir una serie de externalidades positivas. Sin embargo, quizá no sea la mejor forma de fomentar el perfeccionamiento tecnológico. En Corea, la preferencia de las importaciones de tecnología de fácil alcance, por oposición a la inversión directa, estimuló a las empresas locales a invertir en investigación y desarrollo, porque esta actividad se complementó con una serie de medidas que alentaron a la industria a adentrarse en campos más complejos, y al mismo tiempo la obligaron a hacer frente a la competencia de las exportaciones.

Para perfeccionar la tecnología industrial quizás sea necesario intervenir en los regímenes comercial y tecnológico que fomentan la investigación local. De por sí, la apertura a la competencia y la tecnología internacionales quizás no sean suficientes —como ocurrió en España y México— para fomentar la actividad tecnológica. El Banco debe evaluar los factores que, a su juicio, impulsan el proceso de desarrollo tecnológico y la creación de una cultura de investigación y desarrollo, prestando particular atención a los efectos derivados de la importación de insumos tecnológicos, por oposición al desarrollo de la tecnología local.

El dinamismo tecnológico exige una intensa participación del sector privado en las actividades tecnológicas. La función que desempeñan las instituciones públicas en la tecnología debe disminuir con el tiempo para brindar respaldo a las actividades tecnológicas del sector privado. Muy pocos países han superado con éxito esta transición. En el caso de Corea, esto supuso, además de una estrategia clara con respecto al comercio, la industria y la ciencia y la tecnología, la adopción de diversas medidas financieras y fiscales para estimular la investigación y el desarrollo en el sector privado. Sin embargo, en México, la actividad económica formal era muy escasa y casi toda se concentraba en las instituciones públicas. En vista de la naturaleza de las actividades de investigación y desarrollo, las autoridades deben adoptar una política encaminada a estimular estas actividades en el sector privado ofreciendo incentivos, incluidas medidas fiscales y de otro tipo.

Para que la industrialización sea eficiente a todos los niveles hay que desplegar un esfuerzo tecnológico. Aunque hasta la fecha los proyectos de DTI del Banco se han concentrado principalmente en las ERI, deberían ponerse en marcha también en países menos industrializados. En algunos países en desarrollo, lo que quizás se necesite al principio para fomentar la competitividad y la eficiencia sea mejorar los conocimientos prácticos y contar con una eficiente infraestructura tecnológica (en materia de normas, metrología, control de calidad, etcetera) antes de crear centros de investigación y desarrollo más avanzados.

Las tendencias a largo plazo de la tecnología afectan a la competitividad y a las medidas tecnológicas que adopte cada país. Aunque el Banco no puede especializarse en todas estas tecnologías, debe estar al corriente de los aspectos cruciales de tecnologías genéricas en las que los países en desarrollo puedan necesitar orientación. De esta manera, las actividades crediticias de la institución con respecto al desarrollo de la tecnología industrial tendrían mayor sentido.

Es necesario difundir en el Banco documentación sobre DTI y analizar el tema en profundidad. Actualmente, los pocos funcionarios que se dedican a los proyectos de DTI en el Banco entienden la importancia que reviste el desarrollo tecnológico, pero a veces les resulta difícil comunicar sus ideas. Todo esto cobra aún más importancia, habida cuenta de lo importante que es para el Banco la reacción de la oferta y la competitividad que se prevé tengan las reformas de la política comercial e industrial y de la reestructuración de la industria.

Repercusiones en los proyectos

Al financiar la investigación y el desarrollo de las empresas, el Banco debe buscar intermediarios que comprendan en qué consisten estas actividades, que tengan pericia técnica, que conozcan los diversos sectores industriales y que estén comprometidos y dispuestos a asumir riesgos. Por lo tanto, el proyecto sólo debe estar en manos de organismos dinámicos con voluntad de liderazgo y que estén dispuestos a facilitar y supervisar la marcha del mismo en aras de la eficiencia. En general, los intermediarios financieros tradicionales, como los bancos comerciales, no están en condiciones de satisfacer esas necesidades de financiamiento y, por lo tanto, es preferible encomendar estas actividades a instituciones financieras especializadas.

El éxito del financiamiento de la innovación tecnológica en la industria depende de la composición institucional de los intermediarios financieros. Aunque en un principio puede ser necesaria la intervención de las autoridades, el intermediario debe contar con una participación y un respaldo sólidos del sector privado, y con una total autonomía para evitar interferencias burocráticas. La experiencia de Corea y India es un buen ejemplo de la conveniencia de contar con instituciones de gestión privada, que sean sensibles a las necesidades del mercado y tengan relaciones con la industria. Sin embargo, en México, los bancos comerciales de primer nivel tuvieron muy poca participación en los préstamos para tecnología.

El éxito del financiamiento de la tecnología y del capital de riesgo depende en gran medida de la experiencia y la calidad de los funcionarios de las instituciones. Estas no sólo deben atraer y retener personal calificado, sino también seguir aumentando su eficacia a través de toda una serie de programas de capacitación.

Las operaciones de capital de riesgo y de riesgo compartido deben realizarse con gran prudencia, porque no siempre se puede contar con los conocimientos necesarios para ejecutarlas, y cuando existen se tarda en desarrollarlos. En el proyecto de India, las proyecciones con respecto a este financiamiento fueron excesivamente optimistas. Las actividades de riesgo compartido exigen además contar con recursos financieros que permitan una prudente asunción del riesgo. Al organizar el financiamiento de los intermediarios, es necesario contar con algún grado de certeza con respecto a las fuentes de financiamiento y los compromisos del gobierno en materia de asistencia, y con un programa de rembolsos bien concebido.

En todos los países que abarca el presente estudio, a las instituciones de investigación y desarrollo creadas para estudiar la tecnología industrial les ha resultado difícil establecer contactos con empresas manufactureras. La privatización de los centros públicos de investigación plantea varias dificultades, como lo demuestra el caso de México, donde las empresas se mostraron reacias a adquirirlos y administrarlos. Dado que las grandes empresas cuentan normalmente con recursos propios para financiar la investigación y el desarrollo, se debe dar prioridad a la pequeña y mediana empresa en el financiamiento de estas actividades. Ofrecer incentivos financieros al sector privado podría ser un medio idóneo para establecer vínculos entre la pequeña y mediana empresa y los centros de investigación y desarrollo.

Si bien es importante que el sector privado esté representado en los órganos directivos de los centros de investigación y desarrollo, es muy improbable que la participación colectiva de las empresas del sector privado baste para poner en marcha centros privados de investigación y desarrollo, a menos que las autoridades los apoyen firmemente y les brinden asistencia financiera. Además, se podría recurrir a los servicios de las instituciones del sector privado para facilitar los vínculos entre la industria y los centros de investigación y desarrollo.

Todo parece indicar que el mejor enfoque para reforzar los vínculos con respecto a la investigación debería basarse en las siguientes consideraciones: (a) sólo los centros de investigación con una tradición de "servicio a la industria" pueden ser esenciales para fortalecer los vínculos; (b) las industrias, sobre todo la pequeña y mediana empresa, padecen *graves faltas de información y credibilidad* con respecto a la subcontratación de la investigación a los centros. Esto se debe en parte a que no han podido definir con claridad sus necesidades en materia de tecnología y, en parte, al hecho de que desconocen la capacidad de los centros y desconfían de que se respete el "secreto industrial". La mejor forma de resolver estas deficiencias es subvencionando, al menos en parte, el proceso de creación de vínculos y logrando que las empresas se comprometan a aportar recursos financieros. De hecho, en muchos de los proyectos de DTI se reconoció la necesidad de otorgar estas subvenciones, que adoptaron la forma de préstamos en condiciones concesionarias, tasas de interés preferenciales, selección de actividades concretas, etcetera. Este enfoque ha sido acertado, aunque todavía no se ha evaluado sistemáticamente qué forma de respaldo es la más eficiente.

Résumé analytique

Introduction

A travers les projets qu'elle a financés, la Banque a largement contribué au renforcement des capacités technologiques dans les pays emprunteurs. Elle a aidé les emprunteurs à choisir des technologies appropriées, présentant un bon rapport coût-efficacité, et à exploiter leurs installations industrielles de manière efficiente. Souvent, grâce à cet appui, les emprunteurs ont réussi à se doter des moyens nécessaires pour mettre en oeuvre des projets similaires. Mais au départ, et jusqu'aux années 70, le renforcement des capacités technologiques n'a joué qu'un rôle accessoire dans les grandes opérations de prêt de la Banque.

A partir du milieu des années 70, la Banque a aussi commencé à tenir compte de la place de la technologie dans le développement industriel. Après la création du poste de Conseiller pour la science et la technologie, un certain nombre d'études ont été menées en vue du renforcement des moyens scientifiques et techniques dans les pays en développement. La Banque a étudié la situation de quelques-uns de ces pays et l'un des tout premiers de ces rapports visait l'Indonésie (« Problems of Industrial Technology », 1972). Sa première opération de prêt pour le développement technologique industriel a été approuvée en 1975 en faveur d'Israël et s'inscrivait dans le cadre d'un prêt de développement industriel (1116-IS). C'est l'Espagne qui, en 1977, a fait l'objet du premier projet entièrement consacré au développement technologique de l'industrie.

Il a toutefois fallu attendre les années 80 pour que la question du développement technologique de l'industrie soit systématiquement prise en compte au sein de la Banque. Quatre pays ont alors fait l'objet d'une étude comparative et la question du développement technologique a été intégrée aux études sur le secteur de l'industrie dans les nouvelles économies industrielles (NEI). D'importantes composantes technologiques ont été incorporées à certaines opérations et toute une série de projets exclusivement axés sur le développement technologique, là encore essentiellement dans des NEI, ont été préparés et approuvés. Mais les efforts de ce genre sont restés limités et, en dépit de la prise en compte du développement technologique dans les opérations de prêt de la Banque touchant le secteur industriel, peu nombreux sont ceux qui, en dehors du personnel de la Banque directement concerné, avaient véritablement conscience de l'importance du développement des capacités technologiques.

Objectifs de l'étude

La présente étude a pour principal objectif d'évaluer l'impact que les prêts de la Banque en faveur du développement technologique industriel ont eu sur le secteur industriel des pays emprunteurs. Elle essaie notamment d'apprécier les éléments qui, du point de vue de la Banque, déterminent le développement technologique industriel et les politiques qu'elles a recommandées. Elle analyse aussi les résultats obtenus, l'adéquation des objectifs recherchés compte tenu des circonstances, et les facteurs ayant contribué à la réussite ou à l'échec des projets.

L'étude porte essentiellement sur les projets d'aide au développement technologique industriel (projets DTI) réalisés dans six pays : la Corée, l'Espagne, la Hongrie, l'Inde, l'Indonésie et le Mexique. Ces pays ne sont pas les seuls dans lesquels la Banque a financé des projets ayant trait au développement technologique (ou s'y rapportant étroitement), mais ils ont été choisis parce qu'ils reflètent différents types de projets et différentes situations économiques. La Corée, l'Inde et l'Indonésie sont des pays d'Asie n'ayant pas tous atteint le même stade de développement industriel et poursuivant des stratégies différentes en matière d'industrialisation et d'échanges commerciaux. Le Mexique a été choisi parce que c'est un grand pays d'Amérique latine, doté d'un secteur industriel important et diversifié qui a récemment fait l'objet d'un profond mouvement de libéralisation. L'Espagne est l'un des premiers pays sur lesquels la Banque a fait porter ses efforts; sa situation géographique et son stade de développement en font à l'évidence un cas intéressant à étudier. La Hongrie est le seul pays d'Europe de l'Est à avoir reçu de la Banque un prêt pour le financement du développement technologique, et le seul de la région à avoir depuis longtemps renoncé à la planification centralisée.

Cadre d'analyse

L'essentiel de l'effort technologique des pays en développement vise l'acquisition de capacités technologiques, c'est-à-dire de toutes les compétences — techniques, gestionnelles et organisationnelles — dont les entreprises ont besoin pour établir une unité de production, l'exploiter efficacement, l'améliorer et l'agrandir progressivement, et mettre au point de nouveaux produits et procédés. Le développement technologique industriel consiste à renforcer ces capacités technologiques et fait partie intégrante de tout processus d'industrialisation efficace, quel que soit le stade de développement.

Dans la plupart des pays en développement, le développement technologique industriel est synonyme d'une efficience et d'une compétitivité accrues au niveau de l'utilisation de technologies importées. Pour les moins avancés d'entre eux, il implique la maîtrise de techniques simples, largement diffusées et, dans les NEI, il suppose la maîtrise de techniques complexes, à forte intensité d'échelle et de compétences. A terme, il nécessite également un approfondissement des capacités technologiques, c'est-à-dire le passage à des tâches plus complexes et plus exigeantes (adaptation, amélioration, conception, ingénierie, développement et innovation) à l'intérieur des technologies utilisées par le pays. Ce processus d'approfondissement technologique procure divers avantages et génère différents types d'externalités. Il peut entraîner une plus large diffusion de la technologie, un recours accru aux facteurs de production locaux, une plus grande différenciation des produits, un accroissement de la valeur ajoutée, et une meilleure capacité de réaction aux évolutions du marché.

La plupart du temps, les pays en développement n'ont pas les capacités techniques nécessaires pour établir efficacement de nouvelles installations de production, et ces capacités ne peuvent pas simplement être importées de l'étranger dans le cadre de l'acquisition de brevets, d'équipements ou de plans-types. Sauf pour les technologies les plus simples, tout transfert suppose de manière implicite qu'il y ait, sur place, développement des compétences, apprentissage et rassemblement d'informations nouvelles; or, cela ne peut qu'en partie seulement avoir lieu à travers un processus passif d'apprentissage par l'expérience. Il faut un effort conscient et soutenu de la part de l'entrepreneur, et cet effort est coûteux et risqué. De plus, une bonne maîtrise des techniques opérationnelles (savoir comment) ne conduit pas automatiquement à l'acquisition de capacités techniques plus complexes (savoir pourquoi). Il faut généralement prendre la décision stratégique d'investir dans l'élargissement et l'approfondissement des compétences et des connaissances, processus qui comporte davantage de risques et prend plus de temps.

Le développement technologique industriel est fonction du jeu croisé des incitations, des capacités et des institutions. *Le régime des incitations* détermine la « demande » d'effort technologique. Mis à part le besoin de produire, qui est fondamental, les incitations à fournir un effort dans le domaine technique dépendent du contexte macroéconomique et des perspectives de croissance, de la situation sur les marchés de facteurs, du système de protection de la propriété intellectuelle, et de la concurrence tant nationale qu'étrangère. De tous ces éléments, c'est généralement la concurrence (notamment à l'échelle mondiale) qui est le stimulant le plus puissant. Lorsque la concurrence est restreinte, comme c'est le cas dans les systèmes d'échanges hautement protégés, la libéralisation peut être une condition nécessaire pour le développement de capacités techniques compétitives. Toutefois, comme le développement des capacités est un processus lent, risqué et coûteux, l'entreprise qui s'y soumet est pendant un certain temps moins efficiente que celle qui a déjà terminé cette phase d'apprentissage. Par conséquent, afin de promouvoir l'apprentissage de nouvelles technologies, il peut être nécessaire d'assurer une certaine protection aux entreprises qui s'engagent sur cette voie.

Si un système de protection des industries naissantes peut fournir aux nouveaux venus le ballon d'oxygène dont ils ont besoin pour se développer, les interventions de ce genre comportent de nombreux dangers, liés au risque de défaillances des pouvoirs publics. L'histoire récente des pays en développement qui ont cherché à s'industrialiser par le remplacement des importations donne de nombreux exemples d'interventions mal conçues et mal gérées. Un système de protection peut en lui même retarder les investissements dans le développement technologique industriel ou les orienter dans une mauvaise direction, en particulier lorsque la concurrence intérieure est très limitée et que les mesures de protection visent sans différenciation de multiples bénéficiaires. Il convient donc d'instituer des sauvegardes pour s'assurer que les industries naissantes investiront effectivement dans le développement technologique. Les mesures les plus efficaces à cet égard consistent à laisser le plus tôt possible jouer la concurrence du marché, par exemple par la promotion immédiate de la concurrence intérieure, l'orientation rapide de la production vers l'exportation et l'application de programmes de protection limités dans le temps. La réussite du développement technologique industriel nécessite, de la part des pouvoirs publics, la fixation d'objectifs stratégiques précis, des compétences administratives, de la souplesse, un suivi attentif, et la correction ou la sanction des mauvais résultats.

Du côté de l'offre, les principaux déterminants du développement technologique de l'industrie sont les *capacités et les institutions*. Si le renforcement des capacités relève en dernière analyse des entreprises elles-mêmes, celles-ci doivent pouvoir trouver à l'extérieur les facteurs de production qu'elles peuvent difficilement générer elles-mêmes. Trois grands types de ressources leur sont indispensables : des compétences adaptées aux besoins, des moyens financiers pour leurs investissements physiques et humains, et des sources d'information et de technologie pour nourrir leurs propres efforts. Elles ont chacune leur propre marché, qui n'est pas à l'abri de défaillances. Les pouvoirs publics peuvent donc être amenés à prendre des mesures pour assurer la disponibilité des compétences, moyens financiers et informations nécessaires au développement technologique des entreprises.

L'accès à la technologie étrangère en particulier joue un rôle crucial pour le développement technologique. C'est l'une des solutions les plus économiques pour acquérir une nouvelle technologie. Si l'importation d'une technologie étrangère s'accompagne d'un apport de compétences, de formation ou d'autres types d'assistance, l'acquéreur aura moins à faire pour maîtriser cette technologie et suivre son évolution. Le fait de limiter cet accès peut rendre le développement technologique industriel considérablement plus coûteux, ou le retarder dans la mesure où les efforts entrepris localement ne sauraient se substituer à ceux accomplis à l'étranger. Il y a toutefois de nombreux moyens d'accéder aux technologies étrangères, avec des résultats différents du point de vue du développement technologique local. La répartition des ressources entre le développement technologique interne et l'acquisition de technologies étrangères est difficile à établir, et le fait de privilégier l'un ou l'autre des termes de l'équation peut se révéler coûteux ou inefficace. Une dépendance passive à l'égard de l'étranger peut certes déboucher sur de bonnes capacités opérationnelles, mais ce n'est pas forcément le meilleur moyen de renforcer les capacités locales. L'importation de technologies étrangères doit venir s'ajouter aux efforts déployés au niveau local, mais non les remplacer complètement. A partir d'un certain stade, le développement industriel, pour être dynamique et durable, implique toujours un renforcement des capacités locales en matière de conception, de développement et d'innovation. Sinon, les segments de l'industrie ayant la plus haute valeur ajoutée demeurent inaccessibles.

Au sens large, les institutions fixent les « règles du jeu » applicables à l'exploitation des entreprises et à leurs transactions sur les marchés des facteurs ou des produits. Ce cadre doit être transparent, stable et prévisible, et il ne doit pas établir de discriminations fondées sur l'origine, la structure du capital ou la taille des entreprises. Par institutions au sens strict, il faut entendre les organisations mises en place pour appuyer le fonctionnement des différents marchés qui jouent un rôle dans le développement technologique industriel, à savoir le marché de la main-d'oeuvre, le marché des capitaux et le marché de l'information. Parmi les principales, on peut citer les établissements d'enseignement et de formation, les institutions de financement du développement et les sociétés de capital-risque, les instituts scientifiques et techniques et autres organismes ayant pour mission d'appuyer la sous-traitance, les petites entreprises et la diffusion de l'information. Il est largement admis que le renforcement des institutions est essentiel pour le développement sous toutes ses formes, et qu'il joue un rôle crucial dans la promotion du développement technologique industriel.

Le problème de la technologie dans les pays étudiés

Le problème de la technologie ne se posait pas du tout dans les mêmes termes dans les six pays étudiés. Ils étaient certes confrontés à un certain nombre de problèmes communs, en raison du caractère pratiquement universel des défaillances du marché, qu'il s'agisse des capitaux, de la main-d'oeuvre qualifiée ou de l'information dont ont besoin les entreprises pour leurs investissements technologiques. Toutefois, ces défaillances n'avaient pas partout la même ampleur, ni le même impact. Et, plus important, les incitations à investir dans la technologie variaient fortement d'un pays à l'autre, tout comme étaient très différentes les « traditions » établies au fil du temps, poussant tel pays à investir dans l'innovation locale et tel autre à acquérir des techniques plus compliquées dans les pays plus avancés. Ces traditions, elles mêmes fruits de la situation géographique, de l'histoire et des politiques antérieures du pays, semblent exercer une influence sur le développement technologique industriel, quel que soit par ailleurs l'impact des incitations résultant de la politique commerciale et industrielle.

L'Espagne, dotée depuis longtemps d'une importante structure industrielle, avait beaucoup amélioré ses capacités opérationnelles sous l'effet d'une libéralisation progressive et de politiques encourageant activement la restructuration des entreprises et le resserrement des liens avec l'infrastructure technologique et industrielle. Toutefois, ses piètres performances en matière de recherche-développement (R & D), et sa présence relativement discrète (par rapport au reste de la Communauté européenne) dans les secteurs dynamiques de l'industrie manufacturière témoignaient d'une immaturité technologique, situation due à l'absence de traditions technologiques bien établies et sans doute aussi à l'inadéquation du financement du développement technologique industriel et à l'insuffisance de l'infrastructure de soutien.

La Corée s'était dotée d'une structure industrielle solide et diversifiée par des interventions délibérées au niveau des régimes commerciaux et industriels, et en orientant les investissements vers des secteurs bien précis largement contrôlés par des entreprises nationales privées. Pour acquérir de nouvelles technologies, ces sociétés avaient surtout recours à l'achat d'équipements et de licences d'exploitation, et relativement peu à l'investissement direct étranger. Elles avaient donc un défi encore plus important à relever sur le plan technologique, notamment parce qu'elles devaient très vite devenir exportatrices. Lorsque les industries coréennes avaient abordé des activités plus complexes et approché les limites de leur technologie, le développement d'activités locales de R & D était devenu impératif pour le maintien de leur compétitivité à l'échelle mondiale.

Pour se doter des compétences requises pour cet effort, la Corée avait investi massivement dans l'enseignement technique supérieur et pris des mesures en faveur de la formation en entreprise. La mobilisation des ressources nécessaires avait d'abord été laissée aux intermédiaires financiers en place, avec en complément un certain nombre d'instruments destinés à soutenir la R & D dans le cadre des projets approuvés par le *chaebol*, mais rien pour les innovations de moindre envergure et autres formes d'effort technologique. L'infrastructure scientifique et technologique avait reçu d'importantes ressources financières et humaines, et semblait avoir réussi à établir de bonnes relations avec l'industrie. Toutes ces mesures s'étaient traduites par un développement spectaculaire de la R & D dans le secteur privé et par une plus grande ouverture à la technologie, ce qui avait permis à la Corée de réaliser ses principales ambitions industrielles. Les principaux problèmes restant à régler avaient trait aux défaillances des marchés financiers à l'égard des petits projets d'innovation et à l'aide à apporter à l'infrastructure de recherche pour élargir son champ d'activité à l'appui de la stratégie industrielle du gouvernement. C'est sur la solution de ces problèmes que la Banque avait axé son aide au développement technologique.

L'Indonésie avait une structure industrielle beaucoup plus simple que celle des autres pays étudiés et, par conséquent, ses besoins technologiques étaient eux-mêmes simples. Au départ, l'industrie indonésienne était fortement protégée et tournée vers le marché intérieur; la situation s'est améliorée, mais d'importants dispositifs de protection restent en place çà et là, et le rythme de la libéralisation n'est pas clair. L'industrie indonésienne demeure hautement tributaire d'importations pour ses composants et matériels, comme pour la technologie et les compétences, et les firmes locales n'investissent pratiquement pas dans les domaines de l'ingénierie, de la conception et du développement. Toutefois, certaines entreprises, poussées par la libéralisation à investir davantage dans l'apprentissage de technologies et l'efficience opérationnelle, maîtrisent de mieux en mieux des processus complexes. La base de compétences est étroite, et l'absence de tradition industrielle et en matière de recherche ne fait qu'accentuer les difficultés posées par la faiblesse des effectifs de techniciens de haut niveau. Le seul effort concerté en faveur de la technologie est le fait d'un petit nombre d'industries « stratégiques » opérant dans des domaines de pointe sans aucun rapport avec le gros de l'activité de l'industrie privée. A l'exception des éléments servant les industries stratégiques, l'infrastructure scientifique et technologique est peu développée et coupée de la réalité industrielle. Le financement du développement technologique industriel est inexistant. Le problème du DTI en Indonésie recouvre donc de multiples aspects : mesures d'incitation, mécanismes de financement, accès à l'information et liens entre l'industrie et l'infrastructure scientifique et technique.

Le Mexique allie une longue histoire de substitution aux importations à une tradition de forte dépendance à l'égard de technologies importées. Cette stratégie a donné de bons résultats en ce sens qu'elle a permis de créer des industries de transformation et une industrie automobile efficientes; elle a en revanche été peu efficace pour ce qui est de la production de biens d'équipement. Peu d'entreprises mexicaines se sont dotées de capacités de conception et de développement, et les entreprises publiques elles-mêmes préfèrent nettement importer matériels et savoir-faire. De tous les grands pays en voie d'industrialisation, le Mexique est celui où la R & D industrielle est la plus faible, et cela reste vrai actuellement en dépit de la rapide libéralisation de l'économie. La base de compétences est assez bonne. Le pays dispose d'une vaste infrastructure scientifique et technique, mais qui, comme c'est souvent le cas, souffre de l'absence de liens avec la production. Bien que les pouvoirs publics se soient penchés sur la question, le financement des activités technologiques est resté insuffisant. Au Mexique, les problèmes de développement technologique tiennent essentiellement à la réticence des entreprises à investir pour renforcer leurs propres capacités et se charger elles-mêmes d'activités de R & D, ainsi qu'aux lacunes de l'infrastructure scientifique et technique.

Les difficultés du développement technologique industriel en Hongrie au cours des dix dernières années ont été essentiellement liées au système d'incitation, au régime de propriété et au mode de direction des entreprises, et à la politique commerciale. Bien qu'ayant une solide base industrielle et une longue tradition de R & D, le pays, pour n'avoir appliqué que des réformes timides et partielles, n'avait pu tirer pleinement parti de son potentiel et de son expérience technologiques pour rendre son industrie compétitive sur les marchés occidentaux. Il y avait aussi d'autres problèmes. La base de compétences techniques de haut niveau était plus faible que dans les pays d'Europe de l'Ouest. L'infrastructure scientifique et technique était très importante, mais elle était dépassée et manquait de ressources financières. Certaines entreprises néanmoins avaient su maintenir une tradition technologique et les capacités correspondantes. A l'époque, les contraintes au développement technologique industriel tenaient surtout au système d'incitation et au mode de direction et de contrôle et, dans une moindre mesure, à l'inadéquation des moyens financiers et de l'infrastructure de soutien.

L'Inde avait développé sa base industrielle à travers une série d'interventions dont les effets avaient été mitigés, le coût des inefficiences et des retards technologiques paraissant supérieur aux avantages de la diversification. Elle avait poursuivi avec plus de détermination que la plupart des autres pays une stratégie d'autonomie technologique, et investi dans la mise en place d'une vaste infrastructure scientifique et technique. Elle s'était dotée d'une large gamme de capacités technologiques avec une nette croissance des activités de R & D. Toutefois, la base de compétences utilisables dans l'industrie restait relativement limitée et, du fait des distorsions du système d'incitation, l'apprentissage de nouvelles technologies n'avait pas débouché sur des productions réellement compétitives ni sur des innovations. L'infrastructure scientifique et technique était largement déconnectée de la production. L'accès aux technologies étrangères était restreint et le financement du développement technologique industriel encore peu développé. Les besoins technologiques des petites et moyennes entreprises (PME) n'étaient pas pris en compte, et les activités de R & D des grosses entreprises privées étaient inadéquates. Les entreprises publiques, nombreuses et généralement inefficientes, effectuaient certes quelques recherches, mais un petit nombre seulement étaient parvenues à être compétitives. Les problèmes technologiques de l'Inde recouvraient donc de très nombreux aspects et concernaient aussi bien les mécanismes d'incitation que les capacités et les institutions.

Les projets d'aide au développement technologique

Tous les projets d'aide au développement technologique de l'industrie (projets DTI) avaient pour objectif fondamental le renforcement de la compétitivité et de la productivité du secteur industriel et reposaient sur deux grandes hypothèses, que mentionnent la plupart des documents relatifs à ces projets. Premièrement, quel que soit le niveau d'industrialisation, la disponibilité de certaines capacités technologiques est toujours indispensable pour atteindre un degré d'efficience comparable à celui observé à l'échelle mondiale, mais ces capacités doivent être d'autant plus développées et diversifiées que la structure industrielle devient complexe. Cela implique notamment que les pays en développement doivent investir pour se doter de capacités de R & D afin de pouvoir assimiler et tirer le meilleur parti de technologies importées plus perfectionnées. Deuxièmement, certaines mesures doivent être prises pour remédier aux défaillances du marché qui entravent le renforcement des capacités technologiques.

Les projets DTI témoignent d'une prise de conscience aiguë de l'importance du rôle du régime des incitations pour encourager la « demande » de technologie. Vu la nature de ces projets, la question des incitations relevant des politiques macroéconomique, commerciale et industrielle n'y était pas directement abordée. On peut noter toutefois que tous les pays concernés avaient amorcé une certaine libéralisation et on pouvait donc supposer que cela contribuerait à stimuler la demande de technologie. Aussi ces projets avaient-ils pour thème central les défaillances du marché « du côté de l'offre ».

Pour ce qui est des compétences, le manque de personnel qualifié n'avait été considéré comme un obstacle majeur au développement technologique que pour l'Indonésie. Pour les autres pays, les compétences techniques des entreprises et des institutions avaient été jugées amplement suffisantes, mais la plupart des projets prévoyaient cependant une formation en matière de finance, d'évaluation et de gestion.

Concernant les défaillances du marché financier, pratiquement tous les projets, à l'exception de celui pour l'Indonésie, ont mis l'accent sur la nécessité de financer l'activité technologique. Le projet coréen portait exclusivement sur la fourniture de capital-risque et l'introduction d'autres instruments nouveaux pour le financement de l'activité technologique. Les projets mis en oeuvre en Espagne, en Hongrie, en Inde et au Mexique avaient pour thème principal le financement du développement technologique et comportaient aussi des mesures pour remédier aux défaillances des marchés de l'information. Les buts de la composante financière ont varié suivant les pays. En Espagne, il s'agissait de financer l'importation, le développement et la diffusion de certaines technologies dans le cadre d'une stratégie de modification de la culture technologique du pays. Le projet hongrois consistait essentiellement à accorder des prêts pour l'achat à l'Ouest de logiciels et de matériels et technologies modernes pour le contrôle des processus industriels. En Inde, le but était de financer l'importation de technologies et l'effort d'innovation local au moyen de capital-risque, tandis qu'au Mexique et en Corée, il s'agissait de financer aussi bien l'assimilation de technologies étrangères que la commercialisation de technologies locales.

Le renforcement des réseaux d'information et de services techniques répondait généralement à deux objectifs : améliorer les capacités des institutions scientifiques et techniques et établir des liens plus étroits entre ces institutions et l'industrie. Dans trois projets (quatre si l'on y ajoute la composante développement des compétences au sein des organismes publics non affiliés à des ministères en Indonésie), le renforcement des institutions représentait un objectif majeur. En Inde, le projet de la Banque est venu appuyer les réformes engagées par le gouvernement pour donner une orientation plus commerciale à l'infrastructure technologique. Au Mexique, les investissements du projet dans certains instituts de recherche ont été liés à une privatisation partielle des ces organismes. En Hongrie, le projet prévoyait le renforcement des centres de métrologie et de contrôle de la qualité, ainsi que des infrastructures d'appui à la R & D. La nécessité de resserrer les liens entre la recherche et l'industrie a été prise en compte dans la plupart des projets, mais ne semble pas avoir figuré parmi les objectifs immédiats pour la Hongrie et l'Indonésie.

Evaluation

La plupart des documents relatifs aux projets DTI affirment clairement la nécessité de promouvoir le développement des technologies industrielles. D'une manière générale, ils font valoir que, pour rendre les industries existantes compétitives comme pour créer de nouvelles sources d'avantages comparatifs dans le secteur manufacturier, il est indispensable d'investir dans le développement technologique. Le progrès technique y est présenté comme un élément moteur du développement industriel, de la productivité et de la compétitivité dans les pays en développement; il doit être activement recherché car il ne résultera pas automatiquement d'un processus passif d'apprentissage et il exige des entreprises un effort d'investissement dans plusieurs domaines comme la formation, la collecte d'informations, l'ingénierie, les études techniques, et l'expérimentation; il suppose une interaction entre les entreprises et des institutions scientifiques et technologiques capables de leur fournir certains services relevant des « biens publics », et il exige enfin une diversification et un renforcement constants des capacités technologiques parallèlement au développement de l'industrie.

Ces documents reconnaissent les difficultés que peut poser la création de capacités opérationnelles et l'éventuelle nécessité d'un appui des pouvoirs publics. Ils rappellent en outre que la mise en place de capacités opérationnelles ne débouche pas automatiquement sur un renforcement des capacités technologiques. Plus l'industrie se développe et plus ce renforcement est indispensable. L'absence de capacités technologiques de haut niveau compromet non seulement l'aptitude des entreprises locales à se diversifier, à diffuser leurs techniques et à tirer parti des externalités de l'activité technologique, mais aussi leur aptitude à assimiler des techniques plus avancées importées de l'étranger. La R & D sert autant à se tenir à jour des progrès techniques qu'à produire des innovations. En général, l'analyse des besoins de DTI figurant dans les documents des projets étudiés ici repose sur de solides arguments. Cela ne veut pas dire que tous les pays en développement se doivent d'entreprendre immédiatement pareil effort de renforcement de leurs capacités technologiques, ni que les NEI doivent nécessairement engager des activités de R & D pour toutes les techniques de pointe. Cela signifie toutefois qu'il y a des choix à faire tout au long du processus d'industrialisation et que, faute d'entreprendre le travail nécessaire pour se doter de certaines technologies plus avancées ou complexes, le pays risquerait de ne pouvoir accéder aux activités industrielles offrant la plus forte valeur ajoutée.

Pour ce qui est des éléments déterminants du DTI, il est clairement reconnu que le *système d'incitations* a un impact décisif sur l'ampleur et la nature des investissements technologiques et que ce système doit être de nature à encourager le développement de l'industrie dans son ensemble. La décision de la Banque de financer un projet DTI, et la structure donnée a ce projet, dépendent pour une très large part de son analyse du régime d'incitations du pays considéré. Cette approche est parfaitement justifiée dans la mesure où le succès d'investissements à long terme dans le renforcement des capacités et de la R & D dépend très fortement des incitations créées par l'environnement macroéconomique et concurrentiel, celles-ci devant déterminer la « demande » de DTI.

Bien que la nature précise des incitations requises n'y soit pas explicitée, les documents des projets DTI et d'autres études de la Banque sur les questions d'industrialisation permettent de se faire une idée des vues de la Banque quant au système d'incitations le plus propice au développement des capacités. Ce régime doit satisfaire à quatre conditions. Il faut d'abord que le régime commercial soit libéral et de plus en plus ouvert à la concurrence internationale sous toutes ses formes (au plan des importations comme des exportations). Les bonnes raisons que l'on peut avoir de protéger certaines activités pour encourager le développement technologique de l'industrie sont en général très largement compensées par le risque de voir les choix opérés par les pouvoirs publics se solder par des échecs. Il faut aussi que les entreprises aient pleinement accès aux technologies et aux matériels étrangers sous toutes leurs formes. En troisième lieu, le système d'incitations doit encourager résolument la concurrence interne, en éliminant toutes les barrières artificielles à l'entrée comme à la sortie. Il doit enfin encourager le secteur privé à jouer le rôle qui est le sien.

Cette définition est fondée sur les leçons tirées par la Banque du développement de l'industrie dans de multiples pays ayant adopté des stratégies différentes. Pour des raisons d'ordre théorique aussi bien que pratique, les quatre critères susmentionnées sont tout à fait justifiés. Le développement technologique de l'industrie est fortement stimulé par la concurrence internationale. L'importation de technologies est indispensable au développement des capacités locales et les politiques d'autarcie technologique se révèlent en général désastreuses. La sélectivité n'a guère été couronnée de succès et choisir les technologies gagnantes est une tâche particulièrement difficile. La concurrence interne tend à encourager le progrès technologique, l'efficacité et la croissance. Enfin, le secteur privé est, en règle générale, plus efficace et plus sensible aux signaux du marché que le secteur public.

S'agissant des rapports entre stratégie commerciale et développement technologique, de solides arguments continuent à militer en faveur de la protection des industries naissantes. Les créateurs d'industries nouvelles font forcément face à des coûts supplémentaires parce qu'ils doivent acquérir des compétences techniques que d'autres ont déjà maîtrisées. Les arguments en faveur d'interventions des pouvoirs publics tiennent aux défaillances du marché qui peuvent affecter ce processus d'apprentissage, qu'il s'agisse d'externalités (fuites de connaissances et compétences au profit d'autres entreprises), de la complémentarité des efforts de développement technologique entre entreprises liées verticalement (l'acquisition de connaissances par une entreprise affecte la compétitivité d'une autre entreprise, sans qu'aucune des deux en tienne compte dans ses décisions d'investissement), de la méconnaissance par les entreprises des avantages d'investissements dans le développement technologique ou de leur incapacité à les prédire convenablement, ou encore de la répugnance extrême des entreprises à prendre des risques et de l'utilisation de taux d'actualisation qui pénalisent la collectivité. L'expérience montre toutefois que les interventions auront d'autant plus de chances d'être utiles qu'elles s'inscrivent dans le cadre d'*un régime fortement orienté vers l'exportation* qui compense les effets démobilisateurs de la protection des industries naissantes, tout en assurant à l'économie les avantages, au plan de la concurrence et de l'information, d'une participation aux échanges mondiaux. En outre, le besoin de protection diminue parallèlement au développement technologique de l'industrie. A mesure que progressent leurs compétences technologiques, les industries doivent être exposées à la concurrence d'importations pour les inciter à poursuivre leur développement technologique, à condition toutefois que cette ouverture ne soit pas si brusque et soudaine qu'elle stoppe le processus d'apprentissage.

A l'heure actuelle, pour la Banque comme pour les pays en développement, le problème immédiat est non pas tant d'encourager les industries naissantes que de restructurer les industries créées sous un régime d'incitations faussé. Là aussi se pose la question du développement technologique et des moyens propres à le favoriser, mais sous une forme différente. Dans le cas des économies dotées d'un certain nombre d'industries arrivées à maturité (ou presque) à l'abri de régimes commerciaux protectionnistes, une libéralisation immédiate s'impose pour leur permettre de tirer parti de leurs avantages comparatifs actuels sur les marchés mondiaux. Cependant, pour les industries susceptibles d'être compétitives, il peut y avoir intérêt à prévoir des programmes progressifs de restructuration et de réapprentissage. L'introduction d'activités nouvelles et complexes peut encore avoir besoin d'être encouragée par des mesures appropriées de politique commerciale. Les documents établis à l'appui des projets DTI ne semblent pas avoir insisté suffisamment sur l'utilité de pareilles mesures pour encourager le développement technologique industriel.

Les prêts de la Banque au titre de projets DTI ont eu des effets différents dans les pays de l'échantillon. Les trois prêts accordés à la Corée ont contribué à encourager la R & D dans les petites et moyennes entreprises qui avaient besoin de capital-risque pour engager de telles activités. En Inde, le projet se poursuit de manière satisfaisante; il a aidé des entreprises industrielles du secteur privé à acquérir des technologies à l'étranger, procuré aux innovateurs une source de capital-risque et engagé un certain nombre de centres de R & D à orienter leur activité en fonction des besoins de l'industrie. En Espagne, le projet a contribué à encourager et à faciliter la recherche et la commercialisation de nouveaux procédés et produits, mais c'est en fait l'adhésion de l'Espagne à la CEE en 1986, et son ouverture aux activités de R & D de la Communauté, qui ont véritablement incité l'industrie espagnole à intensifier ses efforts.

L'impact des prêts de la Banque dans les trois autres pays est moins encourageant. Si le projet réalisé en Indonésie a atteint l'objectif limité d'élargir le réservoir de compétences dont disposait le pays en permettant à des diplômés de poursuivre leur formation à l'étranger, il y a peu de chances qu'il en résulte un renforcement général des capacités technologiques de l'industrie indonésienne. Le projet mexicain n'a pas atteint ses objectifs majeurs, à savoir encourager la mise en place de véritables activités de R & D dans le secteur privé et la privatisation des établissements de recherche. Il est à l'origine toutefois, grâce à l'étude financée dans le cadre du projet, de la définition d'une nouvelle politique technologique. En Hongrie, abstraction faite de l'Office national de métrologie qui a utilisé le prêt de la Banque pour importer de précieux instruments de mesure, nombre des autres bénéficiaires se heurtent à de graves problèmes du fait de la transformation radicale de leurs marchés.

La fourniture de ressources financières, afin d'éliminer l'un des principaux obstacles au développement technologique, était l'un des principaux objectifs des projets DTI de la Banque, sauf en Indonésie. Ces projets ont à juste titre prêté une attention particulière aux besoins des petites et moyennes entreprises, celles-ci étant confrontées à de plus grandes difficultés financières que les grosses sociétés. Les fonds des prêts de la Banque sont allées à la mise au point de techniques locales de même qu'à l'assimilation et à l'adaptation de technologies importées.

Les projets DTI visaient aussi, et à juste titre, le renforcement des institutions d'appui et de leurs liens avec l'industrie, en faisant appel à des solutions différentes selon le pays. En Inde et au Mexique, on a cherché à améliorer aussi bien le fonctionnement de l'infrastructure de R & D que ses liens avec l'industrie. En Corée et en Espagne également, les projets ont visé à renforcer les liens entre la recherche et l'industrie tandis qu'en Indonésie, la formation de chercheurs pour les instituts du pays était le principal objectif.

Les objectifs que la Banque s'était fixés pour remédier « du côté de l'offre » aux défaillances du marché des facteurs, étaient généralement valables. Il est évident que les défaillances du marché financier peuvent affecter le développement technologique de l'industrie, notamment pour les entreprises de taille moyenne, et qu'une infrastructure médiocre offrant un appui insuffisant aux entreprises peut entraver la circulation de l'information et la mise en route de certaines formes d'activité technologique et de recherche-développement. Toutes mesures visant à remédier à ces insuffisances peuvent favoriser l'activité technologique. Leurs avantages peuvent toutefois être plus limités qu'on ne le pensait lors du lancement des projets. Ces mesures peuvent avoir pour effet d'améliorer les capacités opérationnelles plus que de rehausser le niveau de l'effort technologique. *Il n'est pas certain qu'en l'absence d'une forte tradition de recherche-développement, il suffise de mesures d'action sur l'offre pour donner une plus forte impulsion au développement technologique.* Cet aspect du problème n'a pas fait l'objet d'une attention suffisante lors de l'élaboration de certains des projets DTI.

Dans certains cas, en outre, on n'a pas suffisamment tenu compte, pour la conception du projet, de l'histoire et des traditions industrielles du pays. Peut-être avait-t-on pensé que le processus qui sous-tend le développement technologique est le même partout et que tous les pays s'engageraient sur cette voie dès lors qu'on aurait libéralisé le régime des incitations et éliminé les problèmes posés par les défaillances des marchés financiers et les insuffisances de l'accès à l'information. La conception des projets était en général bien adaptée à la situation du pays dans le cas de la Corée et l'Inde. En Indonésie, le projet a pâti de sérieuses erreurs de conception, si l'on considère que l'objectif était d'améliorer les compétences de telle manière que s'en trouvent renforcées les capacités technologiques de l'industrie indonésienne dans son ensemble. Le projet mexicain comportait un élément intéressant de privatisation des établissements de recherche, mais avait laissé en suspens d'importantes questions touchant la mise en oeuvre et l'utilité des liens que l'on voulait créer. Dans le cas des projets espagnol et mexicain, les mesures prévues pour lever les obstacles financiers au développement technologique de l'industrie se sont révélées adéquates pour stimuler les types d'activité technologique existant déjà, mais insuffisantes pour susciter de véritables avancées.

Leçons de l'expérience et recommandations

D'après l'expérience des projets DTI réalisés dans les pays ayant fait l'objet de la présente étude, les éléments qui déterminent les résultats d'un projet paraissent être les suivants :

L'effort de développement technologique doit s'insérer dans le plus large contexte d'une stratégie d'industrialisation, sinon son impact risque d'être limité. La préparation des projets DTI doit reposer sur une approche intégrée pour que soient simultanément traitées toutes les questions relatives aux incitations, aux capacités technologiques et aux institutions.

L'impact d'un projet DTI sur le développement technologique de l'industrie dépend de l'existence d'une stratégie clairement définie et dûment coordonnée. L'efficacité des projets réalisés en Corée tient non seulement à la part importante prise par le gouvernement dans l'orientation de l'économie et en particulier dans le développement industriel du pays, mais aussi au fait qu'il avait su formuler une stratégie explicite de développement technologique. Cela a été le cas, à un moindre degré, dans nombre des autres pays et, le cas échéant, la Banque a insisté pour que l'on effectue une étude en vue de la définition d'une politique technologique.

Etant donné que les projets DTI cherchent habituellement à remédier aux défaillances des marchés des facteurs en agissant sur « l'offre », on ne saurait trop insister sur l'importance cruciale du système d'incitations. Pour encourager le développement technologique de l'industrie, il faut non seulement un bon cadre macroéconomique, mais aussi des politiques commerciales, industrielles et technologiques libérales. Lorsque le régime des incitations est profondément faussé, comme c'était le cas en Hongrie lors du début du projet, même des mesures bien conçues d'action sur l'offre ne peuvent donner l'impulsion voulue. Il convient par conséquent de ne mettre en oeuvre de projets DTI que lorsque l'environnement économique est de nature à en permettre le succès.

La possibilité d'avoir accès à des technologies étrangères est indispensable au développement technologique de l'industrie, et le cas de l'Inde montre bien les effets nocifs de graves restrictions à l'importation de technologies. Cependant, le mode de transfert des technologies étrangères peut influer sur l'ampleur et la nature du développement des capacités nationales. Faire largement appel à des investissements étrangers directs peut être un moyen extrêmement efficace de transférer les connaissances nécessaires à l'exploitation de technologies étrangères, et cela peut avoir nombre d'effets externes bénéfiques. Cependant, cette approche n'est pas forcément le meilleur moyen de renforcer les capacités technologiques du pays. En Corée, la préférence donnée à l'acquisition des technologies dans le cadre d'opérations commerciales plutôt qu'à l'investissement direct a encouragé les entreprises locales à investir dans le renforcement de leurs capacités de R & D parce qu'à l'appui de cette approche, les pouvoirs publics avaient pris tout un ensemble de mesures pour inciter l'industrie à s'engager dans des domaines complexes tout en les forçant à se faire concurrence sur les marchés d'exportation.

Pour renforcer les capacités technologiques de l'industrie, il peut falloir agir aussi sur le régime des échanges commerciaux et technologiques de matière à encourager la recherche locale.

L'ouverture du pays à la concurrence internationale et aux technologies étrangères peut ne pas suffire en elle-même, comme en témoigne le cas de l'Espagne et du Mexique, pour engager les entreprises sur la voie d'améliorations technologiques. Il serait bon que la Banque approfondisse son analyse des éléments moteurs de l'évolution technologique et des facteurs qui sous-tendent la création d'une culture de recherche-développement, en s'attachant plus particulièrement à comparer les effets de l'importation de technologies à ceux d'activités locales de recherche.

Il n'est de véritable essor technologique que lorsque le secteur privé participe activement à l'effort. Les institutions publiques devraient progressivement se désengager et se donner pour mission de soutenir les activités technologiques du secteur privé. Les pays sont très peu nombreux à avoir opéré cette conversion. La Corée l'a fait en alliant l'adoption de stratégies claires dans le domaine du commerce, de l'industrie, de la science et de la technologie à la prise de mesures financières et budgétaires pour encourager la R & D privée. Au Mexique, en revanche, l'activité technologique était extrêmement réduite et relevait presque exclusivement d'institutions publiques. Etant donné la nature des activités de R & D, les pouvoirs publics devraient encourager le secteur privé à s'en charger par la mise en place d'incitations financières et autres.

Un effort dans le domaine technologique est indispensable à une industrialisation efficace, et ce à tous les niveaux. Les projets de DTI ont jusqu'ici principalement concerné les nouvelles économies industrielles, mais les pays moins industrialisés devraient aussi faire l'objet de pareilles opérations. Dans certains pays en développement, il faudra peut-être commencer, pour promouvoir la compétitivité et l'efficacité, par améliorer les compétences techniques et par mettre en place une infrastructure efficace (en matière de normes, de métrologie, de garantie de qualité, et cetera) avant de passer à la création de capacités complexes de recherche-développement.

Les tendances à long terme de la technologie influent sur la compétitivité et sur l'effort technologique de chaque pays. Bien que la Banque ne puisse se spécialiser dans tous les domaines, elle se doit d'avoir une idée des éléments critiques pour lesquels les pays en développement pourraient avoir besoin de ses conseils. Cela lui permettrait d'améliorer la pertinence de ses opérations de prêt à l'appui du développement technologique industriel.

Par la diffusion d'informations et l'ouverture de débats approfondis, la Banque devrait sensibiliser son personnel à la question du développement technologique de l'industrie. Ses projets DTI sont actuellement le fait d'un petit nombre de spécialistes qui connaissent bien les tenants et les aboutissants du développement technologique, mais qui éprouvent souvent des difficultés à partager ce savoir avec les autres membres du personnel. Cet effort d'information et de communication est rendu d'autant plus important par l'intérêt que porte la Banque à la réaction de l'offre et à la compétitivité parmi les objectifs de ses opérations de restructuration industrielle et de réforme des politiques commerciales et industrielles.

Implications des projets

Lorsque ses prêts doivent aider les entreprises à engager des activités de recherche-développement, la Banque devrait chercher des intermédiaires qui connaissent bien ce domaine d'activité et disposent de l'expertise nécessaire, qui aient l'expérience de divers secteurs industriels, et qui soient résolus à faire le nécessaire pour aboutir et prêts à prendre des risques. La responsabilité des projets ne devrait donc être confiée qu'à des organisations dynamiques disposées à guider, faciliter et suivre les progrès dans un souci d'efficacité. Les intermédiaires financiers usuels, comme les banques commerciales, ne sont généralement pas équipés pour faire face aux exigences de ce type de financement et il est souhaitable de faire appel à des établissements financiers spécialisés.

Le succès du financement de l'innovation technologique dans l'industrie dépend de la structure institutionnelle de l'intermédiaire financier. Bien que la présence des pouvoirs publics soit parfois nécessaire au départ, l'intermédiaire choisi doit bénéficier d'une forte participation et d'un vigoureux soutien du secteur privé, ainsi que d'une entière autonomie pour éviter toutes interférences bureaucratiques. L'expérience de la Corée et de l'Inde illustre les avantages que présentent des institutions gérées par le secteur privé, sensibles aux besoins du marché et ayant des rapports étroits avec l'industrie. Au Mexique, en revanche, les banques commerciales de premier rang n'ont guère participé aux prêts d'aide au développement technologique.

La réussite du financement de l'innovation technologique et de la fourniture de capital-risque est fonction, dans une très large mesure, de l'expérience et de la qualité du personnel des institutions concernées. L'institution chargée de l'opération doit être capable non seulement d'attirer et de conserver un personnel qualifié, mais aussi d'améliorer constamment son efficacité par divers programmes de formation.

Les formules impliquant la fourniture de capital-risque et le partage des risques sont à utiliser avec la plus grande prudence parce que les compétences qu'exige leur gestion sont chose assez rare et ne s'acquièrent qu'avec le temps. Dans le cas de l'Inde, l'acceptabilité de ce type de financement avait été surestimée. Les formules de partage des risques supposent aussi la disponibilité de ressources financières telles qu'il soit possible de prendre des risques calculés. Pour organiser le financement des intermédiaires, il convient d'être raisonnablement certain des sources de financement, des engagements pris par les pouvoirs publics en matière d'assistance, et de l'existence d'un programme bien conçu de redistribution.

Dans tous les pays couverts par la présente étude, les institutions de R & D chargées des technologies industrielles ont éprouvé des difficultés à établir des liens avec les entreprises manufacturières. La privatisation des instituts publics de recherche se heurte à diverses difficultés, comme le montre l'expérience du Mexique où les entreprises se sont montrées peu disposées à prendre en charge la propriété et la gestion de ces instituts. Etant donné que les grosses entreprises ont habituellement leurs propres ressources de R & D, il conviendrait de donner la priorité au financement de ce type de services pour les petites et moyennes entreprises. La fourniture d'incitations financières au secteur privé pourrait faciliter la création de liens entre les petites et moyennes entreprises et les centres de recherche-développement.

S'il est important que le secteur privé soit représenté dans les organes de décision des centres publics de R & D, il est hautement improbable que l'on puisse mettre en place des établissements privés de R & D grâce à une participation collective des entreprises privées sans un solide soutien et une assistance financière des pouvoirs publics. On pourrait faire appel aux services d'institutions privées pour faciliter la création de liens entre l'industrie et les centres de R & D.

La meilleure approche pour renforcer ces liens semble être de reconnaître clairement : (a) que seuls les établissements de recherche qui, par principe et par tradition, sont « au service de l'entreprise » peuvent apporter une aide utile; et (b) que les sociétés, et notamment les petites et moyennes entreprises, hésiteront sérieusement *par manque d'information et de confiance*, à sous-traiter des travaux de recherche à de tels établissements. Le problème réside pour partie dans leur incapacité à définir clairement leurs propres besoins technologiques. Il tient en partie aussi à ce qu'elles connaissent mal les possibilités offertes par ces établissements et redoutent la divulgation d'informations confidentielles. Le meilleur moyen d'éliminer ces contraintes est de favoriser l'établissement de ces liens par le versement de subventions, à tout le moins au départ, tout en s'assurant que les entreprises prennent certains engagements financiers. Nombre des projets DTI ont reconnu la nécessité de pareilles subventions et ont fait appel pour cela à diverses formules : prêts conditionnels, taux d'intérêt préférentiels, ciblage d'activités déterminées, et cetera. Cette démarche était tout à fait justifiée, mais il reste à déterminer, par une évaluation systématique, la forme de soutien la plus efficace.

1. The analytical framework

The nature of industrial technology development

The importance of technological activity and innovation to industrial competitiveness is widely accepted in the context of developed industrial countries. It is less widely understood that conscious technological effort is equally important for developing countries, even though they are essentially importers of manufacturing technologies and not "innovators" in the normal sense of the term.[1] Much of this effort is directed at the acquisition of technological capabilities (TCs). TCs in industry may be defined as the skills—technical, managerial, and organizational—that are necessary for enterprises to set up a plant, utilize it efficiently, improve and expand it over time, and develop new products and processes. They comprise a broad range of functions, from the routine ones needed for the factory shopfloor to the sophisticated ones needed for advanced research. *Industrial technology development (ITD) refers to the growth of these technological capabilities.* ITD is a necessary and integral part of the process of efficient industrial development, and many of the factors that affect the latter also determine the former.

The appropriate content of ITD varies by the level of development. In advanced industrial countries it may mean the ability to enter high-technology industries or to push back the frontiers of innovation. In most developing countries it means the ability to become more efficient and competitive in the technologies they have imported across a range of manufacturing activity. There are, nevertheless, wide variations in ITD needs *within* the developing world. In the least-developed countries with new and relatively shallow industrial structures, ITD comprises the mastery of simple and well-diffused technologies and some adaptation of imported technologies to local conditions. In the more advanced newly-industrializing economies (NIEs), ITD involves mastering complex, scale- and skill-intensive technologies and entering into more advanced technological areas of activity within each technology.

The process of successful industrial development necessarily involves the *deepening of technological capabilities over time.* This is so for two reasons. First, industrial progress involves the *entry into higher value-added activities.* Any country starting on industrialization begins with low technology, low wage activities such as final assembly or the manufacture of simple items like garments.[2] As it develops, it takes on more difficult activities that require greater skills and know-how to operate. This requires the extension of capabilities across new, more difficult industrial activities. Second, it involves *undertaking more complex and demanding technological tasks* within the technologies that the country is using. It has to move, in other words, from simple assembly or final touch manufacturing to the undertaking of more adaptation, improvement, design, development, and finally innovation.[3] This requires progressively greater understanding of the principles underlying manufacturing technologies.

This process of deepening technological capabilities has various benefits. The ability to adapt, improve, and develop technologies locally can generate various externalities. It can lead to more widespread diffusion of technology, greater use of local inputs, more product differentiation, and the ability to respond more effectively to changes in market conditions. The externalities can be greater if the activities in which capabilities are developed are themselves more dynamic, in terms of their pace of technical change and their linkages with the rest of the industrial sector. The recent literature on "new growth theories" suggests that one of the factors behind economic success has been the ability of some countries to specialize in industries with greater learning potential and external benefits.[4]

Many of these benefits and externalities are reduced if a country remains wholly or largely dependent on imported technologies (that is, it transforms the industrial structure by engaging in more complex manufacturing activities without greatly deepening local technological content). The case for technological deepening is not a case for technological "self reliance" that was fashionable in some countries in the early days of development planning. Clearly, all countries, even the most technologically advanced, depend on foreign technological inputs in order to specialize efficiently. It is, instead, a case for moving up the skill and knowledge ladder in technical activity. It is the effort to capture some of the rewards and spillovers that innovative ability generates.

Most developing countries with large industrial sectors, especially the dynamic NIEs, regard the deepening of local design and development capabilities as an objective of industrial policy. Their experience suggests, however, that there is *no single optimal path* of technological development. There are many viable strategic choices in the level of dependence a country has on foreign as opposed to domestic sources of knowledge—the *national "make-or-buy" decision* in technology—depending on the size and resources of the country, its strategic objectives in industry, and the success of its government in implementing such objectives.[5]

While the need for ITD clearly grows with the level of industrial complexity, it should not be assumed that progress up the technological ladder is simple and automatic. Even the first stages of mastering existing technologies are not easy. The capabilities needed to deploy efficiently a new manufacturing facility (or a new process, or even a significantly larger scale of operations) are generally not present in most developing countries. Nor are these capabilities easily transferred from abroad as part of the sale of equipment or patents and blueprints. There are "tacit" elements in the transfer of all but the simplest technologies that call for indigenous skill creation, learning, and the collection of new information, only part of which occurs as a passive process of learning by doing. The process requires conscious and sustained effort on the part of the manufacturer.[6] Thus, different enterprises may end up with different levels of mastery of the same technology depending on the extent and effectiveness of their investments in capability acquisition.

Though technological learning within a firm builds upon its existing base of TCs, the course of ITD is not entirely predictable. The pace and direction of technological development are determined by the efforts made by each firm, the efficiency of those efforts, and the technological strategy it adopts. It is important to note that *successful mastery of operational technology may not automatically lead to the* *development of deeper TCs*. There may be a discrete jump in the level of effort and resources needed to move from the efficient operation of a technology to the ability to substantially modify it or develop new products and processes: in the literature this is sometimes referred to as the distinction between "know-how" and "know-why." Know-how is the set of capabilities needed to manage a given technology on the shopfloor, know-why the understanding of the underlying technical and engineering principles. Know-how does not automatically lead to know-why in most industrial technologies—*a strategic decision* has to be made to invest in the more risky and prolonged process of gaining the extra knowledge and skills required (often by means of formal research and development).

While the process of ITD essentially involves efforts at the level of manufacturing enterprises, these efforts do not occur in isolation. Each enterprise invests in its capability development in an *intricate web of linkages* of information, skill, and product exchange with the outside world. This world includes other manufacturers, service firms, consultants, as well as a variety of institutions dealing with finance, skills, and technology support. Efficient ITD involves that the intensity and ease of interchange improve as each of these actors becomes more specialized in its own area of competence. The strength of these linkages, and the level of development and dynamism of linked enterprises and institutions, are all critical to ITD within individual firms. The efficient functioning of factor markets and the growth of interfirm linkages is thus a vital determinant of technological progress.

The nature of the technology[7] is of great importance to the process and requirements of ITD. Each technology has differing demands of skill, know-how, scale, and institutional and interfirm linkages for its efficient utilization, and these differences are crucial to the analysis of ITD strategy. Thus, in a least-developed country the appropriate way to promote ITD may be the assembly/manufacture of bicycles or simple agricultural tools, while in an NIE like Korea it may encompass advanced electronics or fiber optics.

At the firm level, investment in ITD faces the risks and uncertainties that affect all forms of investment. It is, therefore, strongly influenced by the macroeconomic environment and the state of relevant factor and product markets. Each of these is affected by *government policies*. This may be just as (or perhaps more) important as policies to raise investment in physical facilities, or to achieve efficient resource allocation in a static sense. These determinants of ITD are discussed at greater length in the following section.

Determinants of ITD and policy implications

The determinants of ITD may be divided into three groups: the *incentive framework* (which determines the "demand" side of capability building); *capabilities* (defined here as the "supply" of the three necessary elements of ITD—*human capital, finance, and information*); and *institutions*. The lines between them may not be very distinct, and the factors may interact with each other in complex ways. Nevertheless, it is analytically useful to separate them conceptually to have a simple framework for evaluating policies on ITD. It must be noted, however, that it is the interactions of these factors more than their individual impact that determine a country's industrial performance.

The incentive framework

The set of market and nonmarket incentives facing the firm determine the "demand" for technological effort. The most fundamental incentive for a firm to develop its technological capabilities arises initially from the need to get into production. This is true regardless of the nature of the trade and industrial regime, as long as the firm wants to succeed commercially and has the managerial autonomy to invest in ITD. However, the extent to which it invests in its capabilities to become internationally competitive, and the extent to which it sustains its efforts to adapt to changing conditions and diversify or deepen its base of capabilities, depends on incentives arising from the external environment and government policies.

The *macroeconomic environment and growth prospects* for major markets, domestic or foreign, are clearly strong influences on decisions to invest in ITD. *Ceteris paribus*, a stable, predictable, and high-growth environment is far more conducive to ITD investments than any other. As with any long-term investment, low rates of inflation, interest rates that reflect the opportunity cost of capital, and realistic exchange rates, are the prerequisites of healthy and economically sound ITD activity.

The *rate of technological progress internationally* also affects the optimal pace and content of ITD. No modern manufacturing technology is static, and no developing country can afford to ignore world technological trends if it wishes to stay internationally competitive. The rate of technical change is very different across activities, and the incentives thrown out for ITD effort vary accordingly.[8] In all cases, however, *indigenous technological effort is critical to coping with technical progress.*

The most important incentives to ITD arise from competition, both domestic and foreign. Competitive markets provide the most potent stimulus to investments in capability acquisition, and correct market signals guide firms in investing to the right extent, and in the right forms, in ITD. Thus, artificial restraints to competition can hold back ITD investments, or can lead firms to develop the wrong kinds of capabilities.[9] Many developing countries impose such restraints.

Domestic competition is often held back by barriers to entry by investment licensing, entry controls by size, ownership requirements, restraints on firm growth or diversification, and so on. Though there is a need for regulation to ensure competitive market behavior and observance of the legal rules of the game, the array of restrictions actually imposed in many countries often serves to distort the pattern of industrial activity and generate rents for enterprises that can manipulate the system to their advantage. Domestic competition by itself may not, however, be able to stimulate fully competitive ITD if it takes place in isolation from foreign competition. Highly protected industries in developing countries tend to lag technologically even if there is domestic competition, because the average level of technical efficiency within domestic industry can be low and use of new technologies may lag behind world levels.

Exposure to *world competition* is thus a more powerful incentive to ITD in developing countries. This may take three forms: competition in domestic markets from imports, competition in export markets, or *both* together. If technological capabilities were acquired and deepened costlessly and rapidly, there would be little reason to intervene in either form of competition, or to distinguish between them. However, because the process of capability development takes time and investment, there is a period during which the enterprise is less efficient than one that has already undergone the learning process.[10] This period of "infancy" becomes important for policy especially in the context of competition from developed countries, which have much greater experience of industrialization and much better functioning factor markets and institutions.[11] In developing countries this may lead to a *preference for export market competition over import competition*, the former allowing for a margin of protection in the domestic market that acts as a cushion for the learning period while providing an effective stimulus to ITD.

The risk of underinvestment in ITD applies to both the gaining of *technological mastery* and to *technological deepening*. However, the policy measures needed to induce manufacturing firms to invest in these two forms of ITD may be quite different. Know-how development needs a shorter learning period than know-why development. It is less risky, and can rely on continuing inputs of foreign technology for all the complex design and other tasks. The development of deeper know-why capabilities needs more time, involves more uncertainty, and requires that foreign knowledge be used as an input into local research and development (R&D) efforts rather than a replacement for them.[12] The kind of infant industry protection needed may therefore be different, depending on whether the objective is to promote operational ITD or research capabilities. The latter needs, apart from the normal learning period, the *stimulation of a different strategic attitude to investments in indigenous R&D relative to importing technology*. It may thus call for specific interventions directed at R&D and technology imports, to shift the industrial drive towards technological deepening. The deepening of ITD also seems to call for special measures to promote the *local capital-goods industry*, since this industry can act as an important vehicle for "embodying" technical progress (even minor adaptations), interacting with user industries to utilize their learning in the design of new equipment, and for disseminating this learning to different user industries.[13]

The experience of the larger East Asian NIEs suggests, however, that *carefully designed interventions can produce high rates of industrial and technological development*.[14] In the case of Korea, technologically the most dynamic of the NIEs, strong export orientation combined with infant industry protection, granted to a relatively few activities at a time, provided a powerful and effective spur to ITD.[15] Equally important, trade interventions were carefully monitored and supported by local capability building measures (see below). The deepening of local capabilities was promoted by encouraging private-sector R&D by a variety of measures (including early entry into export markets), fostering the production of increasingly sophisticated capital goods (while continuing to import extensively other equipment, especially for export activities), investing in public-sector R&D institutions that had strong links with domestic industry, and controlling the entry of foreign investors to minimize the dependence of local enterprises on "ready made" technologies.

The negative aspects of protection also need to be stressed. While infant industry protection can provide the "breathing space" in which new entrants can develop their capabilities, there are many potential dangers in such interventions. Protection can itself retard or distort the process of investing in ITD, especially if domestic competition is weak and the protection is granted in a widespread and indiscriminate manner. To ensure that infant industries invest in ITD, therefore, safeguards have to be instituted. The most effective safeguards are those that introduce market competition at the earliest possible time, such as immediate promotion of domestic competition, early entry into export markets, and time-bound programs of protection (with the level of protection declining over time) as industries mature and become competitive. Successful ITD requires a clear strategic objective, administrative skills, flexibility, careful monitoring, and the correction or penalization of poor performance.

These policies are difficult to design and implement effectively. The informational and skill requirements are large, and there is a constant danger of hijacking of policies by rent-seeking agents or by those who stand to lose from exposure to world competition. Trade interventions to promote infant industries run particularly large risks of *government failure*. Much of the recent history of import-substituting industrialization in developing countries is replete with interventions that were poorly designed and badly implemented, and so held back competitive ITD. Where badly done, trade interventions can impose heavy and prolonged costs on a developing economy. Reversing their damage can itself be a painful and difficult process.

Other incentives to ITD arise from factor markets. Changes in relative factor prices and availability can lead to considerable technological activity. It is important for policy purposes that these changes reflect true economic values to the enterprises concerned. Artificial input scarcities (as are often the case in inward-oriented economies) can distort ITD by forcing firms to develop costly substitutes, often of low quality, that retard international competitiveness. Inflexibilities and uncertainties in labor markets can also retard or distort the pattern of investment and capability building, as can imperfections in capital markets. Access to information, technology, and technical support services provide incentives to ITD development; these are markets taken up below in the discussion of capabilities.

Finally, the regime for contracts and intellectual property rights sets the legal stage for ITD. Intellectual property legislation covers patents, trademarks, copyrights, and trade secrets. Without adequate protection for these types of intellectual property, incentives for firms to create new technologies or to transfer proprietary technologies from abroad may be greatly reduced. Many developing countries have rather weak protection for intellectual property, or are lax in enforcing the protection that does exist. Many are not party to international patent conventions. This may affect their access to foreign technologies. More importantly for ITD, a weak intellectual property protection system may deter local innovation as the process of industrialization deepens. In contrast, a strong system can enhance the attractiveness of the country for foreign investors, and allow local firms and institutions to enter into joint technological activities with foreign counterparts.

Capabilities: human capital, finance, and information

Given the "demand" for ITD from the incentive framework, the supply response of the industrial sector depends on its access to some basic building blocks. While the final capability building takes place inside the manufacturing firms, firms have to depend on external sources for inputs that they cannot create easily. The three major building blocks to which firms need recourse are skills of the appropriate kinds, financing for physical and capability investment, and access to information and technology to feed into inhouse efforts. Each of these has its own markets. Each may suffer from market failures. That such market failures exist is borne out by the fact that all developed industrial countries have, over a long period of time, invested in setting up specific mechanisms and institutions to provide for education, training, technology finance, science infrastructure, and research institutions.

The significance of *skills* for the success of ITD is evident. Basic worker skills (literacy and numeracy) are necessary for almost all forms of industrial development. As industry moves into more complex products, specific types of higher technical (and other) skills become essential to efficient operation. Even "simple" industries like garments or footwear need some high-level skills to operate at world standards of cost and quality. More difficult industries, especially those involving engineering activity, have greater demands of advanced skills. Some modern technologies even call for close interaction between science and engineering manpower. Since many of these skills are specific to the technology being deployed (that is, a textile engineer cannot design chemical plant or automobiles), it is not only the total quantity (and quality) of technical skills produced that is relevant but also their composition and relevance.

Industrial enterprises can create a significant amount of human capital with their own efforts, formal or informal. However, they need a base of educated manpower to work with, and this base can only be provided by the national education system. The education "market" needs considerable policy intervention to ensure that adequate quantities of manpower, with the appropriate ranges of skills of the right quality, are produced to enable industry to operate and grow efficiently. Industrial success in the NIEs has been closely linked to their investments in education, especially technical education and vocational training.[16] Of equal importance have been the science and technology policies and their continued efforts to remove the pervasive managerial and manpower shortages. The training provided by the firms themselves is also an important determinant of ITD, and also suffers from the risk of market failure. The amount of employee training provided depends on the firms' awareness of the benefits to be derived from investments in training, and the possibility of recouping the returns from those investments. If firms do not realize the gains to be had from training, or if there is a significant risk that trained manpower will leave the firm, the private returns to training will fall short of the social returns, and firms will underinvest in training.

The ability of the capital market to finance investments in ITD is another crucial element. At low levels of industrialization, when firms are small and specialized in easy technologies with low capital requirements and limited possibilities of improvements, the absence of a capital market with the capacity to finance ITD in new areas may not be a major handicap. The normal financing of working capital will cover technology development activities that are not separated into formal research and development. Even at this level, however, there is a risk that such financing will not meet needs for training and other needs that are not strictly working capital needs, and for which small firms may not be able to offer collateral. As industrial development proceeds, moreover, the financing gap may grow more serious. ITD will increasingly take the form of long-term and risky investments in new technologies that the financial system may not be willing or able to provide for. Capital-market failures are widely recognized in developing countries, but this particular type of failure is accepted also in developed countries.

Firm-level ITD has to draw heavily on information from other sources. This includes the import of capital goods and licensed technologies from the advanced countries, advice and services from consultants or equipment suppliers, information from component and equipment suppliers, competitors, and a range of inputs from the technology infrastructure (extension services, standards, metrology, basic research, contract R&D, and so on). Since a very substantial part of the technological information for most industrial activity in developing countries comes from overseas, access to foreign technology is a critical determinant of ITD. Such access provides one of the most economical ways of gaining the initial input of a new technology. If accompanied by skills, training, and other assistance, it also reduces the tasks that the recipient has to do to master and keep up with the technology. Restricting such access can raise the cost of ITD enormously, or can retard the process to the extent that local efforts cannot substitute for foreign ones.

The correct allocation of resources between creating technology at home and buying it abroad is a complex matter and overreliance on either may be costly or inefficient. Passive dependence on foreign technology may lead to good operational capabilities, but in striving to move to the best practice operational frontier, countries may need to develop and deepen their own adaptive capabilities including design and engineering based on imported technologies. In this, foreign technology should be an input into local efforts and not entirely a substitute for it. Different countries strike different balances between imported technologies and domestic technological effort, depending on their size, location, strategies, resources, and so on (this is brought out clearly in the country case studies). Whatever the choice made between foreign and local technologies, after a certain level dynamic and sustained industrial development always involves some further deepening of domestic capabilities in innovative activities.[17] This does not mean that technological deepening of this nature should be of immediate concern to many developing countries or that the NIEs need necessarily enter into R&D activities in all the most advanced technologies. It does, however, mean that in the process of industrial development choices may have to be constantly made to enter certain more sophisticated and complex areas of technology. Otherwise the highest value-added segments of industry may remain out of reach.

The import of foreign technologies itself requires information and negotiating skills. Many developing countries seek to improve their bargaining positions in international technology markets by intervening heavily in foreign direct investment (FDI) and licensing. This has generally turned out to be counterproductive. Heavy interventions in technology imports have tended to reduce the quality of technology inflows and lead to technological obsolescence. The most successful countries like Korea, and Japan before it, have allowed massive imports of technology, often at very high prices, but helped importers by providing information (on alternative technologies, sources, and prices) that individual firms would find too costly to collect on their own. At the same time, they have invested in local absorptive and innovation capabilities so that imports of technology complemented rather than substituted for indigenous ITD. Thus, setting an appropriate framework for the imports of technology is a very important part of ITD policies.

Local information support for ITD comes partly from other enterprises and partly from the infrastructure of science and technology institutions. The promotion of inter-firm and inter-industry linkages is a critical component of technological development. Specialization and subcontracting tend to grow naturally over the course of industrial development. In most developing economies, however, the growth is slow and may need to be encouraged. In particular, large enterprises that start with imported technologies tend to get "ready made" linkages with suppliers overseas, and tend not to invest in building up local sources because of the costs of searching and transferring skills and know-how to small local firms. There are thus market failures in linkage creation that need corrective policies to increase the efficiency of potential local suppliers.[18]

Institutions

In the broadest sense, institutions provide the "rules of the game" within which enterprises operate and enter into contracts in the markets for factors and products. The lack of an appropriate contractual environment can hold back ITD because it can raise transactions costs and the riskiness of long-term investments (which necessarily require long-term commitments). It is now increasingly accepted that the private sector has a key role to play in industrial development. In order to realize the potential of the private sector it is imperative to set up and enforce an appropriate legal framework that recognizes private property and contracts, and to remove regulatory impediments to efficient economic activity.[19] This framework should be transparent, stable, and predictable, and should not discriminate between industrial actors according to origin, ownership, or size.

For present purposes, institutions in the narrower sense refer to the organizations set up to support the functioning of the skill, capital, and information markets that are relevant to ITD. The main ones are education and training institutes, development-finance and venture-capital institutions, science and technology institutions, and others that support subcontracting, small-scale enterprises, and information flows. Institution building is widely accepted as essential to development in all its forms. In the context of ITD also, the strengthening of deficient markets requires "market friendly" interventions to set up the appropriate institutions.

Linkages with the science and technology (S&T) infrastructure raises different sets of issues. Thus S&T infrastructure is generally in the public domain because of the "public goods" characteristics of many of its products (that is, private suppliers would not be able to appropriate the benefits sufficiently to make it profitable to supply them). The relevance of this infrastructure to ITD varies with the stage of industrialization. In early stages, simple testing, quality assurance, and extension and information services are the most important needs. Simply informing enterprises of the need to invest in capability development, and showing them how to go about it, may be a critical function at this level. In later stages, standards, metrology, applied and basic research, and coordination of information become predominant as firms grow and mature sufficiently to internalize many technological functions. However, even in mature industrial economies there is a great need for information on technology, especially by small- and medium-scale enterprises (SMEs). Many developed countries have technology information services for SMEs, with Japan having perhaps the most extensive and supportive government network of services.[20]

In developing countries, the greatest problem with the science and technology infrastructure (apart from the shortage of human resources to operate it efficiently) has been its lack of effective linkages with the productive sector. Most developing countries have set up networks of technology institutions, but few have been able to harness them to raise productive efficiency in industrial enterprises. This does not mean that the institutions are unnecessary for ITD. They are vital to meeting certain needs, and their utility grows with the level of industrial complexity, but policies must be designed to link them intimately to the needs of manufacturing enterprises.

Conclusions

In conclusion, the process of ITD should be seen as the outcome of a complex interaction between incentives, capabilities, and institutions. Policies to promote ITD have, therefore, to systematically address each of these sets of factors. Just focusing on one may lead to lopsided development. A conducive incentive structure can summon forth healthy ITD only to the extent that the skill, information, and institutional base permits, while highly developed educational and technology structures may not lead to technological dynamism if the incentive structure is distorted or if infant learning is not fostered.

ITD policies can try to improve the incentive or capabilities environment for firms to invest in developing their technologies. They can also act directly on the firms to encourage them to undertake more in-house technological and training efforts. Thus, many governments offer fiscal incentives to R&D and training by industrial firms. They sometimes help firms to restructure themselves to move from loss-making, obsolete technologies to new, profitable technologies. Some governments, most notably the Korean, deliberately foster the growth of large conglomerate firms that can extract maximum benefits from economies of scale and scope, and also internalize deficient capital markets. However, this type of highly selective intervention can also be very costly if it goes wrong. As noted earlier, most governments lack the analytical and administrative capacities,

TABLE 1.1: DETERMINANTS OF INDUSTRIAL TECHNOLOGY DEVELOPMENT

Demand side	*Supply-side capabilities and institutions*				
Incentives	*Institutional setting*	*Capability requirements*	*Support from outside*	*Enterprise level efforts*	*Institutions*
Macroeconomic conditions	Rules of the game	Skills	Technology imports	In-house training	Educational
Trade regime	Regulatory framework	Capital	Foreign direct investment	Internally generated funds	Technical and vocational
Industrial policy		Information	Other technological information	In-house R&D	Science and technology infrastructure, standards, metrology, R&D, testing and quality control, technology extension services, engineering and design, small-scale enterprise support, among others
Factor prices availability				Restructuring	Financial institutions
Fiscal incentives for ITD					Venture capital
Liberal regime					Management institutes and productivity councils
Intellectual property rights					Others

as well as the political strength, to undertake such policies efficiently. The granting of more functional (that is, less firm-specific) incentives, on R&D or training, may be less prone to error or abuse.

These various determinants of ITD, including firm-level policies, are shown in schematic form in Table 1.1. The table provides a checklist to classify, describe, and evaluate technology projects. Not each project is expected to cover every aspect of ITD policy: this would be neither possible nor desirable. However, projects may be assessed as to whether they showed adequate understanding of the process of ITD and of the priorities in any given country. Given their particular objectives, moreover, it can be assessed if they were consistent with other facets of ITD, and if they were formulated to achieve their stated objectives.

Notes

1. There is now a large literature on technological development in developing countries. For some important contributions see C. J. Dahlman, B. Ross-Larson, and L. E. Westphal, "Managing Technological Development: Lessons from Newly Industrializing Countries," *World Development*, 1987, pp. 759–775; J. M. Katz (ed.), *Technology Generation in Latin American Manufacturing*, London: Macmillan, 1987; J. Enos, *The Creation of Technological Capabilities in Developing Countries*, London: Pinter, 1992; S. Lall, "Technological Capabilities and Industrialization," *World Development*, 1992, pp. 165–86; H. Pack and L. E. Westphal, "Industrial Strategy and Technological Change: Theory versus Reality," *Journal of Development Economics*, 1986, pp. 87–128.

2. This is established statistically by H. B. Chenery and associates, *Industrialization and Growth*, New York: Oxford University Press, 1986.

3. See Michael Porter, *The Competitive Advantage of Nations*, New York: Free Press, 1990.

4. See, for instance, A. Young, "Learning by Doing and the Dynamic Effects of International Trade," *Quarterly Journal of Economics*, 1991, pp. 369–406.

5. See Sanjaya Lall, "Explaining Industrial Success in the Developing World," in V. N. Balasubramanyam and S. Lall (eds.), *Current Issues in Development Economics*, London: Macmillan, 1991.

6. For a longer exposition and references to related work done in the Bank and elsewhere, see the Operations Evaluation Department (OED), *World Bank Support for Industrialization in Korea, India, and Indonesia*, World Bank, 1992.

7. The nature of the technology may be defined as its complexity, minimum scale requirements, skill needs, speed of change, product design characteristics, process engineering needs, nature of

supplier and subcontracting linkages, and the need for research backup and testing facilities.

8. In some activities, the import of equipment combined with some local design and absorption effort may suffice, while in others considerable licensing and local research and development may be necessary. Similarly, in some industries, low wages and the use of somewhat older technologies may allow the country to preserve its competitiveness; in others, the utilization state-of-the-art technologies may be essential.

9. Empirical work on capability building suggests, for instance, that highly inward-oriented regimes tend to induce firms to develop skills to use local materials and to "stretch" the use of equipment rather than to raise quality, lower material use, or lower costs. Similarly, restraints on entry and exit are conducive to technological sloth and poor manufacturing practice.

10. In the words of John Stuart Mill: "It cannot be expected that individuals should, at their own risk, or rather to their certain loss, introduce a new manufacture, and bear the burden of carrying on until the producers have been educated up to the level of those with whom the processes are traditional. A protecting duty, continued for a reasonable time, might sometimes be the least inconvenient mode in which the nation can tax itself for the support of such an experiment." *Principles of Political Economy* (1848).

11. The case for infant industry protection is well known and has important implications for developing countries. There may be four types of market failures that adversely affect enterprise decisions to invest in capability development: (a) there may be capital-market failures that deter enterprises from investing in risky activities or in technological deepening; (b) the enterprises may not have the information to predict (even roughly) the course of learning, and in early stages of industrialization, the learning process itself has to be learned [see J. E. Stiglitz, "Learning to Learn, Localized and Technological Progress," in P. Dasgupta and P. Stoneman (eds.), *Economic Policy and Technological Development*, Cambridge: Cambridge University Press, 1987].; (c) there may be externalities in the learning process (see K. J. Arrow, "Economic Welfare and the Allocation of Resources for Innovation," in *The Rate and Direction of Innovative Activity*, Princeton: Princeton University Press, 1962; and Pack and Westphal, 1986, op. cit.); or (d) there may be exceptional risk aversion among new entrants to the industrial scene that leads them to discount the future at a higher rate than society does, and again leads to underinvestment in long-term capability acquisition.

12. On the learning period for developing know-why capabilities in complex engineering industries in Korea, see S. Jacobsson, "The Length of the Learning Period: Evidence from the Korean Engineering Industry," *World Development*, 1993, pp. 407–420.

13. This argument is made in the context of the industrial development of the US by Nathan Rosenberg, *Perspectives on Technology*, Cambridge: Cambridge University Press, 1986.

14. See OED, 1992, op. cit. and S. Lall, 1991, op. cit.

15. See L. E. Westphal, "Industrial Policy in an Export-Propelled Economy: Lessons from South Korea's Experience," *Journal of Economic Perspectives*, 1990, Vol. 4, no. 3, pp. 41–59.

16. See the *World Development Report 1991*, Washington, DC: World Bank.

17. Even those newly industrializing economies, such as Singapore, that based their industrial development on foreign direct investment and the concomitant technology transfer now believe that the deepening of technological capability is both necessary and dependent on their own investment in those activities (see "The Strategic Economic Plan, Towards a Developed Nation," Ministry of Trade and Industry, Singapore, 1991).

18. The problems of linkage creation are much more severe in most centrally planned economies, like Hungary in the present study, where the evolution of the industrial structure has been distorted and production is dominated by large, highly vertically integrated public enterprises.

19. See D. Khatkhate, *The Regulatory Impediments to the Private Industrial Sector Development in Asia*, World Bank Discussion Paper No. 177, 1992.

20. See the Office of Technology Assessment, *Making Things Better: Competing in Manufacturing*, Washington, DC: US Senate, 1990.

2. Background to case studies

Introduction

This chapter describes the economic and technological background of the six sample countries covered in this study: Hungary, India, Indonesia, Korea, Mexico, and Spain. These are not the only countries in which the World Bank has undertaken technology development (or closely related) projects, but the choice was made to reflect different types of projects and different economic settings. The choice of India, Indonesia, and Korea was based on the same reasons as their inclusion in the OED study of the Bank's approach to industrialization in the NIEs (1991)—different Asian countries at different stages of industrialization and pursuing different trade and industrial strategies. Mexico was chosen as a major Latin American country with a sizable and diverse industrial sector that has recently undergone a sweeping liberalization program. Spain was the location of the Bank's first complete industrial technology development project (there was an industrial technology component in the Industrial Development Loan approved in 1975 for Israel, Loan 1116-IS); its location and stage of development have evident points of interest. Finally, Hungary is the only Central and East European country to have a technology loan from the Bank. It is, in addition, the only country in that region that abolished central planning a long time (some two decades) ago. Given its long established and heavy industrial sector, its experience is unique in the present context.

This chapter starts by describing briefly the level of technological development in these countries. It then outlines the determinants of ITD in each; and it concludes with a synthesis of the "technological challenges" facing the sample countries—the challenges that the Bank's projects were trying to meet.

Technological background

It is difficult to rank technologically countries at different levels of development, with different sizes and resources, in an unambiguous manner. Nevertheless, the sample countries' technological development can be viewed and assessed on a combination of industrial growth and deepening, competitiveness of their enterprises, development of local capabilities to assimilate and build upon new industrial technologies, and the ability to enter into design and development of industrial products.[1]

A few tables are presented at the start to "set the scene" on technology. The first deals with rates of growth of manufacturing output and exports for the sample countries. These are shown for 1965–80 and 1980–90 in Table 2.1, with data taken from the World Bank's *World Development Report 1992*. This shows the spectacular performance of Korea, with Indonesia (from a much lower base) not far behind. India has a poor initial performance but a reasonable record

TABLE 2.1: GROWTH RATES OF MANUFACTURING OUTPUT AND TOTAL EXPORTS
(average percent per annum)

	Manufacturing		*Total exports*	
	1965–80	*1980–90*	*1965–80*	*1980–90*
Spain[a]	5.9	0.4	12.4	7.4
Korea	18.7	12.7	27.2	12.8
Indonesia	12	12.5	9.6	2.8
Mexico	7.4	1.4	7.7	3.4
Hungary[b]	6.4	-0.5	..	5.5
India	4.5	7.1	3	6.5

a. Period 2, 1980–88 only, from the World Bank's *World Development Report 1990*.
b. Manufacturing growth rates not available. Data are for industrial production.

in the 1980s, with the opposite true of the other countries.

The next table concerns R&D performance. Table 2.2 presents data on R&D in the sample countries for the most recent year for which figures are available. The figures are broken down into R&D by source of finance (government and productive enterprises, with "other" not shown). It is not possible to get comparable data on industrial R&D, so R&D financed by productive enterprises serves as the nearest approximation.

It appears that Hungary leads the sample in terms of research effort, both in total and in the proportion financed by productive enterprises. Of the others, Korea is the largest investor in R&D, with its lead particularly marked in research financed by enterprises. Indonesia and Mexico have very little or no R&D financed by enterprises; India is very low; and Spain has some enterprise financed R&D, but low for a country of its income and industrialization levels. These figures have to be understood in the context of other features of these economies, and they are taken in turn below.

Spain has the largest industrial sector in the sample, and its industrial sector is diverse and of long standing. Although the country is now too rich to be counted as a developing country, its industrial sector has some features that are similar to some other countries in the sample. Spain also went through an inward-oriented phase with a large role entrusted to the public sector to lead its industry into heavy activities and to catalyze local R&D. However, Spain started from a much higher industrial base than most developing countries and always maintained close technical and trading links with neighboring European countries. It grew rapidly in this phase, before gradually integrating its economy into western Europe and becoming a full member of the European Economic Community (EEC) in 1986. Its rate of growth was, nevertheless, modest by NIE standards throughout the period, with barely positive figures over the 1980s. Its heavy industry had pockets of technological excellence, but also large patches of obsolescence and inefficiency. Spanish industry was weak in machinery manufacture and had an established tradition of depending on imported equipment and technology from more advanced European neighbors. The structure of industry still has a relatively high weight for light consumer goods (food, textiles, and garments account for 28 percent of total industrial production), while capital goods (excluding transport equipment) account for only 10 percent.

TABLE 2.2: R&D EXPENDITURES OF SAMPLE COUNTRIES
(most recent year)

	Spain	*Korea*	*Indonesia*	*Mexico*	*Hungary*	*India*
Total R&D (% of GDP)	0.9	2.1	0.3	0.3	2.7	1.0
R&D financed by productive enterprises (% of total R&D)	40	82	[1–5]	10	77	12
R&D financed by government (% of total R&D)	55	18	[over 90]	90	21	88
R&D financed by productive enterprises (% of GDP)	0.36	1.7	0.0	0.03	2.1	0.1

Notes: Figures in square brackets are estimates. According to sources from the United Nations Educational, Scientific and Cultural Organization (UNESCO), only 1 percent of R&D in Mexico is financed by productive enterprises. Sources in Mexico estimate the figure to be around 10 percent; this is the figure used here.
Sources: UNESCO, *Statistical Yearbook 1990*, and various country sources.

The gradual exposure to the full forces of world competition allowed Spanish industry to upgrade itself over the past two decades, though some of its industries are still protected by the EEC's common external tariff against competition from the Far East. Its export performance has been respectable (total exports grew by 12.4 percent per annum during 1965–80 and by 7.4 percent during 1980–90), showing broad-based competitiveness, but most of the growth has been in medium-to-low-technology activities. In comparison to other European Community(EC) countries, Spain has been losing ground in advanced industries with high income elasticities of demand. Nevertheless, Spanish industry has shown the capacity to absorb and utilize effectively a range of imported technologies for other industries, and to maintain a competitive edge despite rising wages.

These capabilities have gone together with marked deficiencies on the innovative front. Industry had limited capabilities for local design, engineering, and product development. The traditional dependence of Spanish industry on imported technologies was reinforced rather than reversed by its liberalization. The main exception to this trend was the group of publicly owned enterprises in strategic industries. Spanish private industry did increase its investments in R&D, but its purpose was mainly absorptive and the volumes were low (see below). R&D activity was highly concentrated, and much of industry remained outside its ambit. Thus, Spanish industry displayed a mixture of well-developed capabilities in operation and assimilation, especially in relatively mature industries, but weak capabilities in innovation and entry into high-technology activities. The government viewed this situation with concern because of its implications for long-term growth and dynamic comparative advantage.

Korea is one of the most successful industrializers in the developing world. Starting from a small manufacturing base in the 1950s, it was able to mount an industrial strategy that led to sustained and high rates of output growth over several decades. This growth was marked by a constant deepening and diversification of the industrial structure, in terms both of raising the local content of intermediate and capital-goods inputs and of moving into heavier industries. Manufacturing moved steadily from simple labor-intensive activities into basic intermediates, then into capital goods and durables, and within these into more skill- and technology-intensive products. This structural transformation of industry gave Korea a base of industry that is probably unparalleled in the developing world for range, sophistication, and depth.

Moreover, this was accomplished in a relatively short period of time.

While a number of developing countries have managed to build heavy industry, none has been able to combine this process with the level of competitiveness that Korea achieved. It started with relatively efficient export-oriented light manufacturing, then entered more complex activities aimed at domestic markets. Given the learning periods involved in mastering the technologies and achieving fairly high levels of domestic content, these new activities were brought to world levels of efficiency in relatively short periods. By the latter part of the 1980s, Korea had entered several activities of a level of sophistication and competitiveness that could match many advanced industrial countries. These activities displayed considerable local mastery of the technology, since they were largely under the control of local enterprises and personnel. They were based on systematic technological effort to understand and build upon the technologies. Over time, these efforts evolved into high levels of formal research and development, with impressive results in terms of the successful design of "frontier" products of great complexity.

Indonesia does not have a long industrial history. Its manufacturing base, despite healthy rates of growth since the 1960s, is still relatively small, and much of it is concentrated in traditional, low-productivity activities. It completed the first stages on import substitution in the early 80s, and made some progress into heavier process and engineering industries. However, the main success in broadening the industrial structure has been in resource-based processing, much of it aimed for exports; the engineering sector (in particular capital goods) remains weak, with high dependence on imported components and almost no local engineering, design, and development capability. Reliance on foreign technology and skills is pervasive in all modern industry.

There has been impressive growth in manufactured exports since the launching of a program of reform in 1985. Much of this has been due to resource-intensive activities and the relocation of labor-intensive assembly activities from developed countries and the NIEs. However, there has also been growth in exports of other manufactures, some in complex and heavy process industries (steel, fertilizers, chemicals, cement, paper) and a significant proportion of it in locally owned enterprises. This suggests that certain process activities are maturing by developing the skills and know-how to operate near world levels of efficiency. The development is still localized, and large parts of the industrial sector, especially in engineering goods, continue to be backward and high cost. There is practically no investment in R&D by industry, and the level of industrial technological activity and innovativeness is distinctly lower than the other countries in this sample.

Mexico has, like India, a long history of inward-looking industrialization. Combined with good natural resources and a respectable base of human capital, it has built up a large and diversified industrial sector that enjoyed healthy (but not spectacular) rates of growth until the 1980s. In that decade it suffered from a debt crisis and related recession and adjustment. From the mid-1980s it launched a drastic change in its trade and industrial regime, and is experiencing a revival in growth rates. In its import-substituting period it developed a range of heavy industry, particularly in the process industries and automobiles. Rather like Spain, its industrial equipment manufacturing and advanced electronics sectors remained relatively weak, and the industrial deepening process was highly reliant on foreign equipment, design, and technology; Mexico was the largest relative importer of technology among the large industrializing countries. There was also a strong foreign presence in most advanced sectors of industry, though there existed a number of strong local conglomerate groups with considerable industrial experience and capabilities.

Mexican industry did not, despite its traditional inward orientation, suffer the distortions and isolation that India did. The level of protection in Mexico was considerably lower, and industrial interventions far less. The strong foreign presence, continuous large inflows of foreign technology, and its location next to a highly industrialized economy kept it from developing similar technological lags and high-cost production, though they served to reduce the need to invest in local capabilities in research and development. Many of its import-substituting industries matured over time, and after liberalization led its export thrust (heavy industry accounted for 88 percent of Mexico's increase in manufactured exports over 1980–89). Thus, these industries accumulated considerable operational capabilities, which coexisted with a lack of technological deepening in terms of local design and development. Mexico has one of the poorest industrial R&D performances among the major industrializing countries, which particularly affected capital-goods manufacture and high-technology activities. Unlike India and Korea, its industrial strategy aimed at import substituting for production but not for technology: the result was reasonable operational capabilities in some areas and poor capabilities in others.

Hungary is unique in this group of countries. Its socialist background combined with its long experience of gradual and hesitant reform within the socialist framework make it very unusual even in its region. Hungarian industry was highly developed at the end of the second world war, and was well integrated into the trade network of western Europe. A number of enterprises had an established tradition of innovative R&D. With the communist takeover, industrial growth initially accelerated and the structure deepened along the areas of specialization assigned to Hungary by the Council of Mutual Economic Assistance (CMEA). The rate of growth slackened over time (and turned negative in the 1980s) as a consequence of macroeconomic problems, growing difficulties in the CMEA, and the inherent competitive weaknesses engendered by the mode of ownership, competition, specialization, and technical effort. Despite having a diverse and deep industrial structure, the capabilities that Hungary possessed were skewed, narrow, and geared to its own particular market situation. There were pockets of dynamism and efficiency, and some of the older enterprises managed to sustain their research tradition. But on the whole the industrial sector, overwhelmingly in state ownership, suffered from growing technological lags. Managerial and marketing skills were relatively underdeveloped, and soft budgets led to considerable slack and inefficiency in a protected environment.

There were, however, areas in which Hungarian industry was competitive in Western markets. About half its exports were sold to the West in the late 1980s, some (like buses, trucks, and pharmaceuticals) in fairly demanding activities and based on considerable local R&D. The gradual reforms that were launched in 1968 allowed greater managerial autonomy over time, and in the mid-1980s enterprises were able to trade directly and import technology and equipment. Unlike other CMEA countries, Hungarian enterprises could invest in in-house R&D rather than depend on ministerial research institutes for all their technological needs. These factors gave them some flexibility and exposure to the West, and permitted a certain capability development. However, the distorted incentive structure and rigidities in factor markets ultimately overwhelmed these advantages, so that Hungarian industry was relatively undynamic, largely uncompetitive, and technologically backward in many new high-technology activities.

India started its industrial drive in the 1950s with a large, diverse, and long-established industrial base. Given the large size of the domestic market, the existence of a thriving entrepreneurial class, good infrastructure, and a reasonable presence in world markets (after the second world war, India was the largest exporter of manufactures in the developing world), there were high hopes for India's industrial development. The first phase of growth was respectable, but after the mid-1960s there was a marked deceleration. There was significant improvement in the 1980s, followed by a relapse at the end of the decade. Over the period as a whole, India's industrial performance was relatively weak, well below plan targets and with constant shortages and bottlenecks. Nevertheless, over the period the sector was considerably deepened and diversified. There was a high degree of vertical integration, and the deliberate pursuit of self-reliance gave India a very broad manufacturing and engineering base, predominantly owned by nationals, capable of meeting a large proportion of its industrial needs.

The general competitiveness of Indian industry apparently declined as industrialization proceeded. While some of the new industries did achieve reasonable levels of efficiency, many did not. Imported technologies were often mastered, but in a static sense and rarely improved. Costs of production were usually high, quality poor, and productivity extremely low. Most industries lagged increasingly behind international "best practice" in process technologies and product designs. Combined with a trade regime that discouraged exports, India's manufactured export performance was abysmal in comparison to other developing economies with significant industrial sectors. There were signs of growing technological capabilities in several industries, but these capabilities were often diverted into "making do" and diversifying into protected (or permitted) activities rather than achieving competitiveness. Even potential competitiveness was not properly exploited in world markets, though India became a fairly large exporter of industrial technologies. There was notable growth in R&D activity, but much of it was in the public laboratories and did not contribute to industrial innovation. Thus, a range of deeper industrial capabilities did develop, but they did not lead to broad-based competitiveness in manufacturing or to industrial dynamism.

In summary, therefore, there is a very mixed picture for the technological capabilities of the countries in this sample. Korea is probably the clear leader on most counts, with the highest rates of growth and the largest and most technologically advanced exports. But the others have some areas of strength and some weaknesses. India has a diverse set of capabilities but huge inefficiencies. Indonesia has a shallow and young industrial sector with improving operational skills. Furthermore, Indonesia is almost completely dependent on foreign technology with little domestic technological efforts. Mexico has a fairly diverse sector with good operational capabilities in process industries, but is extremely dependent on foreign technology for a country of its level of industrial development; its industry is consequently very weak in design and development capabilities. Spain has the largest industrial sector in the group, but with gaps in high technology and equipment industries and weak local innovation. It shows far less dynamism than Korea. Hungary has an artificially deep industrial sector with large areas of lagging technology and skills, but it also has the longest industrial experience and some very innovative firms. The following sections analyze the determinants of these patterns of capabilities.

The economic setting in the sample countries

Macroeconomic policies

The incentive framework for technology development encompasses a range of influences.

Among these, *macroeconomic policies* are among the most important. As far as the case study countries are concerned, *Spain* achieved a long period of sustained economic growth of more than 6 percent per annum between 1961 and 1974. This was assisted by export-oriented economic policies and supported by rapidly rising foreign exchange inflows from tourism, workers' remittances, and foreign private investment. During this period the share of manufacturing in gross national product (GNP) rose from 30 percent to 39 percent. Sharply increased petroleum prices in 1973–74 and the recession in other OECD (Organization for Economic Cooperation and Development) countries caused a reversal in Spanish economic conditions as the balance of payments deteriorated in 1974 and 1975. After borrowing heavily from foreign capital markets to sustain investment, Spain eventually opted for an official devaluation of its currency, leaving it to float from February 1976. The GNP growth had come to a virtual standstill by the beginning of 1976.

Korea maintained a predictable and largely well-managed regime. It mobilized high rates of savings and investments, promoted exports, and motivated its private enterprises to invest in technological development. Except for one period during the late 1970s, the foreign exchange regime was well-managed and oriented to rapid export growth. A number of factors led to macroeconomic instability and a stabilization program was launched in 1979, which succeeded in restoring macro balance by imposing strict financial discipline, exchange rate devaluation, wage restraint, and investment cutbacks.

After a period of macroeconomic mismanagement in the 1960s, the new regime in *Indonesia* pursued stable policies, accompanied by massive public investments programs supported by oil income. The government has insisted on balanced budgets and maintained an open capital account on its balance of payments since the early 1970s. During the 1980s, Indonesia went through a period of macroeconomic stress primarily because of falling oil prices. After an early attempt to ride out the first shock by drawing down its foreign assets, the government launched a major adjustment program in 1983, which was intensified in 1986. It took decisive action to restrain domestic demand and mobilize additional resources, at the same time undertaking policies to develop the nonoil sectors of the economy. In recent years its macroeconomic policy has been a model of effective management in the face of adverse external circumstances.

Mexico has a tradition of sound macroeconomic management. However, it began to experience difficulties in the 1970s when government expenditures expanded rapidly, financed increasingly by inflation tax and foreign borrowing. As inflation rose the real exchange rate started to appreciate. The discovery of new oil reserves alleviated the pressure for stabilization, but by 1982 falling oil prices, rising world interest rates, and massive capital flight led to the debt crisis. The first response was an impressive fiscal adjustment effort (which converted the budget deficit of 7 percent of gross domestic product in 1982 to a surplus of 5 percent in 1984) and a massive devaluation. The collapse of oil prices in 1985–86 led to a second crisis and adjustment response. This involved a further substantial devaluation, which generated inflationary pressures, leading to a further tightening of fiscal and monetary policy, a wage freeze, and a freezing of the nominal exchange rate against the dollar. This has been successful in reducing inflation, and, combined with a debt restructuring package, has brought down real interest rates and attracted substantial foreign investment.

A significant part of *Hungary's* economic problems in the 1980s were due to weak macroeconomic management. The economy performed relatively well until the mid-1970s, when it started to run a large balance of payments deficit brought about by a series of external shocks. Its early response was to borrow rather than adjust and external debt rose rapidly. In 1982 the government launched a stabilization program supported by two International Monetary Fund (IMF) standby arrangements. This stabilization hit investment rather than consumption, and imports of capital goods from the West were curtailed. Exports to convertible currency areas performed poorly and external debt to these areas increased further. This phase of reform did not achieve structural improvements, and in 1985 a new process of stabilization cum adjustment was initiated. Efforts were made to curb the budget deficit, further reduce demand pressures, and tighten the financial control of enterprises. In 1987 these measures were supplemented by International Monetary Fund and World Bank loans, and started to yield positive results; however, the program faltered in 1989 as wage, monetary, and fiscal discipline was relaxed.

India experienced relatively moderate inflation despite substantial expansion of the money supply to finance budget deficits. It succeeded in raising its savings and investment rates, despite low levels of per capita income. However, the emphasis on public investment and the inefficiency of the large public sector led to poor performance and a crowding out of the private sector from industrial activity. After a large devaluation in 1966, India returned to a fixed exchange rate regime for a long period. This, in combination with a highly inward-looking trade regime, led to a very sluggish export performance. In the mid-1980s the government adopted a more flexible and realistic exchange rate policy, which together with some liberalization of the industrial and trade regime led to an impressive industrial growth and export performance. In the late 1980s, however, there was a resurgence of macroeconomic problems that are now being tackled.

Apart from macroeconomic policies, the most important factors affecting ITD are the *nature of the trade regime, access to technology imports foreign direct investment, and the internal competitive regime*. The impact of these in the sample countries is displayed in summary form in Table 2.3.

Trade regime

The trade regime of the sample countries varied from strongly export-oriented to highly inward-looking, with Korea at one extreme and India at the other. However, it is important to note that *each of the countries intervened strongly in trade to foster new industries*, with different *degrees of selectivity, the efficacy of implementation of strategies, and the introduction of offsetting measures to reduce the distortionary effects of protection*. Thus, the incentives given for investments in capability acquisition differed greatly.

Spain had a long-established industrial sector with close trading and technological ties to western European countries before it launched a period of import substitution under Franco. The extent of protection in this phase was relatively mild, and technological ties continued to be close. But the protectionist phase enabled the setting up of several heavy industries (though not advanced capital goods). This period ended by 1959, when Spain started a long process of liberalization that is still going on. In 1986 it joined the EEC, with safeguards for vulnerable industries for seven years. The Community's external tariff currently protects Spanish industry against labor-intensive and other (mainly automotive) exports from East Asia and other developing countries. The gradual liberalization allowed many traditional and modern industries in Spain to adjust and become competitive. However, two major sectors remained weak—advanced capital goods and electronics—and the continuous dependence on foreign technology and equipment retarded the development of a local innovative base. The incentive

TABLE 2.3: INCENTIVE STRUCTURES IN SAMPLE COUNTRIES

	Spain	*Korea*	*Indonesia*	*Mexico*	*Hungary*	*India*
External incentives						
Trade regime	Industrial sector of long standing. Went through import substitution phase until the 1960s, but was never isolated from European industry. Then joined the European Free Trade Association and liberalized gradually. In 1986 joined the European Economic Community (EEC) with some special tariff barriers during the adjustment period. Common tariffs still protect labor-intensive and other sectors.	Strong overall export orientation, with protection of import substitution and export industries by quantity restrictions, tariffs, government procurement. Heavy industry was promoted strongly, especially in the 1970s. Variable effective rates of protection (ERPs), but low rent-seeking. High degree of selectivity as part of industrial strategy. Import-substitution activities moved into export orientation constantly. Cautious liberalization over 1980s.	Early import substitution with heavy interventions followed by strong export promotion since mid-1980s, and some import liberalization. But high and variable ERPs remain, and the future course of liberalization is not clear. Rent-seeking by large conglomerates. Main export thrust coming from resource-based industry and labor-intensive activities relocated from newly industrializing economies (NIEs).	Long history of incentive structure, with typical nonselective pattern. But not as protected and inefficient as India. Did not promote capital-goods industry sufficiently. Some liberalization earlier, but massive opening up since 1985. Manufactured exports grew rapidly, but mainly in capital-intensive process industries and autos that were highly protected.	As industrialized as many western European countries in 1950, with a tradition of research and development. Then four decades of distortion (in relative isolation) and specialization within the Council of Mutual Economic Assistance (CMEA). But kept strong trading links with the West, with some liberalization since 1968. Firms could export on their own in 1980s, so some had good access to information.	Strong, prolonged import substitution with heavy inward bias, only partly offset by export incentives. Structure of protection irrational and protracted, with no economic selectivity. A lot of rent-seeking, favoring large firms. Modest liberalization recently, but tariffs still high. Consumer goods imports banned. High degree of local integration.
Technology imports	No restrictions on technology import (TI). Location made for fairly easy access to world technologies, except for small- and medium-scale enterprises (SMEs) and traditional activities. Highly dependent on advanced equipment imports, local design weak.	Heavy reliance on imported equipment and licenses rather than foreign direct investment. Strong absorptive effort. Supported TI with information. Local consultants protected.	Low indigenous technology base, high reliance on imported equipment, technology, and skills. Very liberal policies on TI by licensing and turnkey projects. No system of screening or support.	Highly dependent on technology imports, especially from the US. Despite nationalist rhetoric, effective reliance on TI was very high in all forms. Public enterprises were among the largest importers of technology and capital goods.	Relatively limited access to Western technology pre-1990, but a lot of licensing and equipment imports in 1970s before the macro situation worsened.	"Self-reliance," low relative imports of all forms of embodied, and disembodied technology. Technology transfer tightly regulated. Hampered access to new technology, especially by SMEs.

Foreign direct investment	Large foreign presence in all sectors of industry and services. Surge in foreign direct investment (FDI) just before and after joining the EEC. Very liberal regime for FDI.	Relatively low, restricted selectively. Nationalist strategy of ownership. Minority ownership preferred. Gradual opening up when own firms large and strong.	Some restrictions on entry earlier, but much eased, especially in export-orientation activity. Private large firms depend heavily on foreign partners in all aspects of technology. FDI advanced in process industries but at low-level assembly in engineering industries.	Largest foreign presence in industry of any large developing country, despite some restrictive policies. Multinational companies (MNCs) in auto industries are leading exporters.	Practically no FDI before 1990. Some best firms sold to MNCs since, but privatization is going slowly. FDI volume not large yet.	Very low, tightly restricted, guided into high-tech export-orientation activity. Majority shares rarely allowed. Local affiliates highly regulated. Some liberalization last two years, but climate still poor relative to East Asia.
Internal incentives						
Competition	No policy barriers to competition. Dualistic structure of SMEs in traditional activities and large conglomerates and foreign affiliates in modern industry.	Domestic competition. promoted, but among *chaebol* established by the government to internalize markets. Entry controlled by the government. Some selective restructuring. SMEs relatively neglected.	Widespread licensing and other controls, but not as restrictive as India. A lot of rent-seeking as a result of the political system and close links with conglomerates.	Domestic competition active. Some large conglomerates dominate private industry. Special programs to promote private sector in selected sectors, but generally few constraints.	Central planning abolished 1968, so some domestic competition, but tightly regulated by the government and labor. Most large firms highly vertically integrated, used to depending on government signals and favors.	Entry/exit/growth and diversification tightly controlled, especially for large monopoly firms. Small-scale enterprise promoted by reservations. Incentive structure highly distorted by controls and rent-seeking.
Public sector role	The national industry institute (INI) played a leading role in advanced industry and invested in research and development. Now being privatized.	Very limited in manufacturing, but very efficient. Generally very supportive of the private sector.	Given role of entering heavy industry. Later strategic industries set up to go into high-tech activity. A lot on inefficiency in public enterprises, and pressure to reform, except for strategic industries that continue to receive privileges but have dubious economic benefits.	Traditionally very large in certain sectors, with usual inefficiencies. Sweeping privatization recently, with only a few sectors reserved for public enterprises.	Almost all large industry in public sector, but some privatized now. Soft budgets until recently, little pressure to invest in industrial technology development.	Given lead role in heavy industry, with many privileges. Hostile attitude to private sector. But public enterprises subject to gross interference. Generally inefficient, loss-making, overmanned, unable exit.

structure remained geared to efficient operation rather than to research and development.

Korea had the most consistent and strong set of incentives for exporting, but combined this with a clear strategy of import substitution throughout the period, aimed at pushing industry into more complex, capital- and technology-intensive activities, and increasing local content of current as well as capital-goods inputs. This strategy was implemented by tariffs, quantitative restrictions, local content rules, and government procurement. The setting offered to exporters was, therefore, a simulation of some of the necessary conditions for free trade, but without a full exposure to import competition. Protection continued to be afforded to export activities, but they were allowed access to inputs at world prices. Effective rates of protection (ERPs) were often high for selected activities for long periods, but with rapid growth in productivity they came down over time. However, nominal protection on most export activities was not necessarily reduced, and imports of competing products were not liberalized until later, and then at a gradual, pre-announced pace. The Korean regime was geared to promoting a relatively few infant industries at any given time. New infants were generally limited in number, carefully monitored for productivity progress, given strong preference in access to credit, supported by capability-building measures, and forced into export markets quickly.

There was little obvious rent-seeking. The harmful effects of protection were offset by the strong pressures and incentives to enter export markets. The protection of the capital-goods sector was undertaken carefully, so as not to handicap exporters, and Korea was one of the largest importers of equipment in the developing world throughout its period of industrialization.

Indonesia followed an Indian-style import-substituting strategy for a long period of its early industrialization, though from a much smaller industrial base. Much of the engineering goods sector did not move beyond the assembly stage, and a large part of the manufacturing sector remains shallow and highly dependent upon imported inputs despite a local content policy. After the mid-1980s there was significant liberalization, but this took the form mainly of strong export promotion and a gradual, hesitant lowering of import barriers rather than a rapid opening to world competition. There was a gratifying response on the manufactured export front, with the bulk of the increase coming from natural resource and labor-intensive industries, but with significant activity also from a number of capital-intensive processing industries that had matured from infancy. The progress of liberalization remains uncertain. ERPs continued to be high and variable. However, unlike Korea earlier, they do not form part of a coherent overall industrial strategy to foster promising infant industries and force them into world markets in a short period. Thus, trade regime incentives for technological learning are muted.

Mexico's long period of import substitution also followed the typical broad, nonselective approach of India, but with two important differences. First, the extent to which protection and other interventions were pushed was considerably less. Second, the heavy industries promoted were mainly in intermediates and consumer durables; the capital-goods sector was not strongly supported and its weakness affected the nature and depth of industrial capability development. The Mexican economy was more exposed to world trends in technology than India's, but the lack of a strong export orientation and a thriving capital-goods sector meant that capabilities did not develop fully and those that did were not fully exploited in the inward-looking period. After some hesitant attempts, Mexico liberalized its trade rapidly in the latter part of the 1980s. This allowed many of the accumulated capabilities to be exploited in export markets, and the bulk of the increase in foreign sales came from heavy industry that would not have been set up in the absence of import substitution. However, the early growth in exports was in the nature of a stock adjustment, and the rate of growth of manufactured exports declined rapidly over 1987 to 1990. The future growth of exports will depend inter alia upon the creation of new capabilities. The incentive regime in Mexico thus facilitated the accumulation of largely operational capabilities, some in very complex activities, but it did not lead to the deepening of those capabilities.

Hungary was perhaps the most industrialized economy of the sample at the end of the second world war, with strong trading links and many firms with independent research capabilities. The long period of communist rule distorted the incentive structure enormously, isolating the economy in large part from the west and enforcing specialization within the CMEA. Enterprises did not deal directly in world markets for a considerable period, though with the abolition of central planning in 1968, and the introduction of relative prices based on world levels, there was a gradual return to more direct interaction with foreign markets. By the late 1980s firms could trade fully with the West, and over half of Hungarian exports were directed at Western markets. This gave some incentives to upgrade technological capabilities, but the protection of the domestic market combined with domestic distortions (below) and restricted access to Western capital goods and technology (exacerbated by severe macroeconomic pressures in the 1980s) led to progressive technological retardation. There was a massive liberalization after 1990, and the incentive system is now strongly conducive to technological upgrading.

India had the most consistent strategy of inward-oriented industrialization strategy of all the market economies in the sample. The protection it gave was prolonged and was combined with a host of other interventions that were geared to promoting other objectives besides economic efficiency. The overall bias of the regime was to make domestic sales far more profitable than exporting, and a number of specific export-promotion measures failed to offset this bias. The regime promoted the setting up of a large range of industries, with high local content but without regard to competitiveness. The structure of protection was not geared to the learning needs of industries, nor was it offset by other forms of international competition. The lack of a coherent overall strategy was exacerbated by weak implementation, that led to a lot of rent-seeking. The strategy was therefore not conducive to dynamic learning, though a base of capabilities was built up in a variety of difficult activities. Restricted access to new capital goods was particularly harmful for technological upgrading. There has been some liberalization recently, but by most standards the economy remains highly protected and inward-oriented. The accumulated capabilities are still underutilized in world competition.

Technology imports and foreign direct investment

The sample countries had different strategies on access to foreign technology via licensing, turnkey projects, and direct foreign investment. In the post-Franco era, *Spain* had very liberal policies to technology import (TI) and foreign direct investment (FDI). Its gradual integration into the industrially more advanced European Community led to substantial imports of technology and investment and the upgrading of operational capabilities. It did not, however, catalyze a process of indigenous technology creation. The industrial structure retained many of its earlier weaknesses in capital-goods and high-technology manufacturing. Design, R&D, and innovation capabilities continued to lag well behind its Community partners. Access to foreign technology did not feed into a dynamic indigenous ITD process, though the trade and industrial regime was conducive to competitiveness.

India and *Korea* were the most restrictive of the market economies. Both showed a strong preference for nonequity forms of technology import and intervened in licensing to strengthen the position of local firms. However, there were important differences between them. Korea was, as noted, a large importer of capital goods, and used this as its main form of access to foreign technology. However, since this form provides less foreign know-how and technical assistance than all other forms of TI, Korea had to invest heavily in absorption and adaptation in order to meet its objective of export competitiveness. It allowed increasing amounts of licensing and turnkey imports to gain technologies where this was necessary, and only in recent years has it liberalized on foreign investment with majority foreign ownership. Until very recently, India rigorously restricted capital-goods imports as well as other forms of TI, and intervened far more extensively in TI negotiations than Korea (which mainly provided information support to its firms and insisted on the use of local engineering consultants and, to some extent, local equipment). In concert with its trade and internal interventions, the Indian technology regime gave incentives to buy relatively little new technology. Nevertheless, there was significant growth in local design and engineering capabilities, and active internal technology diffusion took root within India.

Indonesia always had a very liberal TI regime but was restrictive on FDI until the mid-1980s. Its undeveloped capital-goods industry and low base of indigenous design and engineering skills made it highly dependent on foreign equipment, engineering services, licenses, and joint ventures. It did not intervene in the TI process or support its firms with information on sources of technology. FDI increased rapidly after policies were eased, and there was a massive influx into resource-based activities and labor-intensive assembly operations. Foreign investors brought in good operating technology, but remained in relatively simple activities apart from the resource processing sectors. Though easy access to foreign technologies and FDI provided incentives for Indonesian enterprises to upgrade their capabilities, low absorptive capacity, distorted incentives, and a passive attitude to ITD detracted from a full exploitation of the potential. Indonesia remains highly dependent on TI for all advanced technological needs, and the local diffusion of technology is weak.

Mexico went through phases of regulating TI and direct investment inflows to promote local technological effort. In general these efforts were ineffective, and Mexican industry (including its large public enterprises) remained very reliant on imported equipment and technology in all forms. Foreign affiliates dominated most of the advanced industrial sectors, though, as noted, the equipment manufacturing and electronics sectors remained underdeveloped. Relative to its size, Mexico had the largest imports of technology import and foreign direct investment of all the NIEs. As the economy became more export-oriented, TI and FDI went up, but the traditional dependence on foreign technology did not decline. As with Indonesia, access to foreign technology *per se* was not enough to cause significant ITD, even when the trade regime became more favorable to competing in world markets.

Hungary had relatively restricted access to Western technologies, and practically no FDI inflows, during the communist period. However, its enterprises did import capital goods from the West whenever permitted, and there were steady but not large inflows of technology via licenses. Access to TI worsened in the 1980s with macroeconomic problems [the COCOM (Coordinating Committee for Multilateral Exports) restrictions also held back the transfer of sensitive technologies from the West], and technological lags grew particularly large in this period. All restrictions have been removed after 1990, but it is too early to say how Hungarian enterprises will react in terms of ITD investment. It is likely that the large enterprises that had a tradition of independent R&D (see below) will use the opportunity to upgrade their innovative capabilities.

The experience of the sample countries suggests that access to foreign technology is necessary for technological upgrading, especially as far as operational capabilities are concerned. It is also necessary for the deepening of ITD into indigenous design and development, but clearly not sufficient. Whether or not the availability of foreign technology is used to deepen local capabilities seems to depend on the tradition of local R&D as well as the incentive framework. There is little evidence from the sample countries that openness to foreign technology per se has resulted in a dynamic and deepened industrial technological capability.

Internal competitive regime

The internal competitive regime consists of the ease of entry and exit, regulations on size, concentration, growth and diversification, and ownership restrictions. Table 2.3 divides these into two broad categories: competition and the role of the public sector. As before, there is a diversity of incentives for ITD in the sample countries.

Spain had free domestic competition, but with an inherited structure of large public enterprises (INI) and powerful private conglomerates. Both are forced to compete in domestic markets and against imports, so that there would seem to be no disincentives to ITD.

Korea promoted vigorous domestic competition, while simultaneously engaging in several policies that aimed at enhancing the international competitiveness. The government built up the large, private conglomerate groups, the *chaebol*, to spearhead the country's drive into heavy industry and international markets, and to undertake the necessary investments, R&D, and marketing. It guided their entry into particular activities, and directed credit to them in accordance with its trade strategies to promote industrial deepening in selected directions. It allocated export targets at the product and even firm level. Exit was tightly regulated, sometimes accelerated when the *chaebol* did not meet performance targets, and sometimes prevented by infusions of resources and deliberate restructuring of firms and industries.

The undertaking of R&D was encouraged along similar lines, with subsidies, persuasion, and support. The public sector was allocated a very limited role; where it did enter industry (as in steel), it was allowed to function autonomously and forced to conform to the same rules as the *chaebol*. This set of policies served to combine coherently Korea's trade, technology import, and industrial strategies with the objectives of realizing scale economies in heavy industry, R&D, and export marketing (and the internalization of the relevant capital markets and risks), promoting vigorous domestic competition, providing access to foreign technology while restricting FDI, and inducing firms to invest heavily in absorbing and building upon imported technologies.

Indonesia also had widespread controls and assigned the public sector a leading role in heavy industry in the early days. Many of these controls and biases were lifted over the 1980s, but the rules of the game remain unclear. There is a lot of discretionary and nontransparent granting of privileges to firms and so a lot of rent-seeking activity. A few large, private conglomerates dominate the industrial and financial scene. The medium-scale industrial sector is underdeveloped and cannot offer competition or linkages to large firms, while small enterprises are either in traditional, low-technology activities or in the export sector where they do not interact with local industrialists. The public sector dominates heavy industry, and within it a few "strategic industries" occupy a privileged position where they can command large resources for technology development. Thus, the internal regime for ITD is unclear and distorted, though not to the same extent as in India. Unlike Korea, Indonesia has not been able to mount strategies that would make use of the conglomerates to lead its technology development.

Mexico has more liberal domestic competition, though it too has dominant public enterprises (PEs) in some activities and a number of large, private conglomerates. There is fairly free domestic competition, which has become far more active over the past decade with the liberalization of entry, exit, and takeovers, and the vigorous privatization of most PEs. There seem to be few internal constraints to incentives for ITD.

Hungary kept tight controls on its (public) enterprises even after the abolition of central planning in 1968. Though enterprise managers gained considerable autonomy and learned how to operate in product and factor markets on their own, domestic competition was muted by soft budgets and a quasi-planning system that persisted until the late 1980s. The government used a number of "indirect regulators" and interventions to govern growth, diversification, and competition. Most firms remained highly vertically integrated, with little subcontracting and efficient specialization. Over time, the government gave a greater role to labor unions in management. Since labor was difficult to shed in any case and was extremely immobile, enterprises found it difficult to formulate clear long-term strategies for technology development. Although the incentive structure was not as bad as in other centrally planned economies in the region, it was considerably worse than most market economies. Despite this, many firms invested in R&D, presumably more for export markets than for internal competition.

India also tightly controlled entry, exit, and growth of its private firms. But its objectives and results were very different from Korea's. The Indian government sought to hand the "commanding heights" of the economy to the public sector, to which it did not allow sufficient autonomy or clear efficiency objectives, and to which it gave soft budgets and markets that were protected internally and externally. The incentives for ITD in the PEs were very limited as a consequence, and only a few with inspired leaders were able to go beyond these constraints and invest in significant and productive R&D. The private sector was, for a long time, subject to pervasive controls on all aspects of investment, diversification, and expansion. This applied particularly to large firms, especially those classified as monopoly houses or under foreign control. The small-scale sector was given inducements and reserved markets, but in a way that distorted resource allocation and growth. There was a lot of corruption and rent-seeking, as the large private firms found ways to manipulate the system to their advantage and diversify excessively within protected markets. There was a significant growth in domestic competition over time, but the general effect of this regime (combined with the protectionist trade strategy) was to stifle incentives for ITD and distort it to meet the constraints created by policy. Exit was practically impossible for PEs and very expensive, slow, and cumbersome for private firms. Many of these regulations have been relaxed, but some remain: in particular, exit is still very difficult, and the public sector remains more or less intact. The incentive regime for technology development is thus better, but far from ideal.

In summary, the incentive framework for ITD was given by a constellation of factors. Stable and predictable macroeconomic settings provided the essential background to healthy ITD. Not all the sample countries provided such a setting on a continuous basis, but most countries enjoyed a fair measure of stability and sustained growth at the time the technology projects were conceived. The strongest economic growth performance was exhibited by Korea, and may have been a factor in promoting its ITD.

Competition clearly was the main driving force behind investments in technology development, and exposure to it forced firms to quickly upgrade their operational capabilities. International competition was a particularly potent stimulus to ITD, but most countries protected their industries to promote entry into technologically demanding industries. This protection was often indiscriminate and overextended, and led to areas of inefficiency and technological stagnation. Only Korea managed to combine infant industry protection with a strong export drive, and was thus able to reap the benefits of the stimulus of international competition while building up an efficient and broad industrial base. The other countries also built up a number of efficient industries that performed well once liberalization was introduced. However, their failure to expose their industries to the stimulus of export competition adversely affected the dynamism of their ITD.

Internal competition varied in vigor across the sample countries. In Korea, Mexico, and Spain it was relatively strong, while in India there were pervasive restrictions arising from industrial policy interventions. Indonesia started with a restrictive industrial policy regime, but gradually liberalized it over time. Internal competition in Hungary remained highly restricted because of the socialist nature of the economy and its concentrated industrial structure.

Access to foreign licensed technology was fairly liberal in all the countries with the exception of Hungary and India. The entry of foreign direct investment was controlled to different extents in these countries: Mexico and Spain, and later Indonesia, permitted high inflows of FDI, while India and Korea placed severe restrictions until recently. In Hungary FDI from the West was practically ruled out by the nature of the economic regime.

Skills

According to the framework used here, the main national capabilities relevant to ITD are skills, finance, and information on technology. These cannot be adequately quantified and compared across different countries, but relevant information on some indicators can be considered usefully. Table 2.4 on human capital in the sample countries presents some relevant data on education and training for technology development. These are on total secondary and tertiary enrollments, enrollments in vocational training, enrollments in science and technology subjects at the tertiary level, and scientists and engineers engaged in R&D. The data may not always be fully comparable, and they do not take account of differences in completion rates, quality of training, or the relevance of the curricula to industrial needs. Nor do they measure a vital element of industrial skill formation, training of employees. In particular, they do not completely portray the situation in various countries when the projects were contemplated. Nevertheless, they are instructive for general comparison.

The table shows that Korea and Spain have the highest skill levels in terms of general education at the secondary and tertiary levels. Korea has a significant edge in terms of tertiary enrollments, while Spain has higher rates of secondary enrollments. Korea is far ahead of all the other developing countries in the sample on both counts (this is true even if a larger sample of NIEs is considered—see the 1992 OED study on industrialization). There are indications that Korean completion rates, quality, and relevance of its education (for industry) are also higher than in most developing countries, and meet the standards of many OECD countries. India and Indonesia are weak performers in the sample. Mexico is better, but Hungary (with the same figure as Mexico for tertiary enrollments) is surprisingly poor for a European country with such a large industrial structure. The level of in-firm investments in training is not fully known. Impressionistic evidence suggests that Korea and Spain invested large amounts in this, with Mexico some distance, and the others much further, behind.

The table also gives the figures for enrollments in tertiary-level science and engineering and in vocational training. Hungary and Spain have the highest enrollments in *vocational training* in the sample, attesting to the long-established system of schooling and its gearing to industrial activity. Korea comes next, with ratios far higher than the other developing countries. India has a surprisingly low enrollment rate, lower even than that of a relative newcomer to industry like Indonesia. Mexico has a respectable figure. As far as *science and engineering enrollments at the tertiary level* (as a percentage of the population) are concerned, Korea is the clear leader, with Spain, followed by Mexico, some distance behind. The others trail much further behind, with Hungary registering a figure between that of India and Indonesia.

The data on numbers of scientists and engineers in R&D (per million population) show, however, that Hungary leads the sample by a significant margin, suggesting that their employment distribution was highly skewed to research even when the R&D performed was not especially innovative or geared to industrial competitiveness and performance. Of the others, Korea is far ahead of Spain (2.5 times), Mexico (6.1 times), Indonesia (7.4 times), and India (11.9 times). This last figure is noteworthy, because of the widely held impression that India has a huge scientific establishment: the absolute figure is large, but in relation to the size of the country it is very small.

Finance

The financing of ITD is fairly well-established in four of the sample countries: India, Korea, Mexico, and Spain. Of these Korea had perhaps the broadest and longest established array of financing mechanisms specifically to assist technological upgrading and R&D. There were direct grants and subsidized credits to enterprises, private research institutes, and official R&D centers that undertook approved R&D projects. There was a special institute to help SMEs, as well as an institute to help firms to commercialize their innovations. India developed some venture-capital institutions over the 1980s, while Mexico set up institutions in the

TABLE 2.4: HUMAN CAPITAL IN SAMPLE COUNTRIES

	Spain	*Korea*	*Indonesia*	*Mexico*	*Hungary*	*India*
Secondary school enrollments as % of relevant age group	105 (1989)	86 (1989)	47 (1989)	53 (1989)	76 (1989)	43 (1989)
Total tertiary enrollments as % of relevant age group	32 (1989)	38 (1989)	8 1989)	15 (1989)	15 (1989)	9 (1986)
Vocational training enrollments as % of population	3.31 (1987)	1.72 (1989)	0.71 (1988)	1.05 (1988)	3.13 (1988)	0.09 (1988)
Tertiary enrollments in science and technology as % of total population[a]	0.54 (1987)	0.86 (1988)	0.08 (1987)	0.45 (1988)	0.11 (1988)	0.16 (1987)
Scientists and engineers in R&D per million population	536 (1987)	1,346 (1988)	183 (1988)	222 (1984)	1,948 (1988)	113 (1986)

a. Subjects included are natural science, mathematics and computer science, and engineering.
Sources: World Bank, *World Development Report 1992;* UNESCO, *Statistical Yearbook 1990.*

early 1970s to finance industry and, as part of this, some technological activity. Spain also set up venture-capital institutions in the 1970s. However, in terms of the volume and effectiveness of technology financing, Korea is clearly in the lead.

Information

The information needs of ITD are diverse, and it is difficult to assess how adequately they are being met. One way may be to look at the proportion of national R&D that is not in the productive sector, that is, that is devoted to S&T infrastructure, universities, defense, and so on. However, these figures capture far more than national investments in technology support functions, and it is not possible to interpret much from them.

These considerations apart, it appears that Korea invested quite a lot in the infrastructure for S&T, while Mexico invested relatively little, with Spain in the middle. If the effectiveness of national technological effort is the criterion by which the information provision is judged, this ranking would not seem to be unreasonable. In the nature of the phenomenon, however, it is not possible to say much more.

Although the assessment of institutions relevant to ITD is difficult on a cross-country basis, it is possible to compare the coverage of technology infrastructure institutions between the sample countries. While each of the countries had a range of institutions dealing with technology, finance, education, training, and infrastructure, many long standing, it appears that the most comprehensive and effective coverage of industrial needs was provided by Korea. India, Mexico, and Spain had set up institutions to meet many industrial needs, but the linkages of their institutions with industry was relatively weak. Indonesia had a poor institutional framework, and a large part of the technology infrastructure has been diverted to uneconomic technological aims.

Their impact on ITD differed considerably, depending partly on the larger economic environment and partly on the organization, staffing, management, and the incentive structures of the institutions themselves. The country studies describe in greater detail some of the institutions involved, but it would not be useful to summarize the analysis here in view of the difficulties in assessing their relative contributions to ITD.

Conclusions: the technological "problem"

The above discussion shows that industrial technological issues differed enormously across these six countries over the past 15 years when all the Bank's technology projects were launched. There were certainly a number of common problems that all countries faced, because of the practically universal nature of market failures in the provision of finance, skills, and information to industrial firms investing in technological activity. However, the weight and incidence of the specific market failures differed. More importantly, the incentive frameworks within which firms were investing in ITD varied greatly, as did the "traditions" that countries had developed over time of investing in local innovative effort as opposed to buying their more difficult technologies from more advanced countries. These traditions, themselves the outcome of location, history, and past policy interventions, appear to exert an independent influence on ITD, regardless of the impact of incentives arising from the trade and industrial regimes. Such traditions are not impervious to change, but they do not shift quickly in response to policy shifts on trade and competition (this will be taken up in the discussion of the projects).

To summarize the technological problems of each of the sample countries:

- *Spain's* large and long-established industrial structure has improved its operational capabilities considerably over a period of gradual liberalization and active policies to restructure firms and raise linkages with the S&T infrastructure. The economy has the right incentive structure for ITD, with the exception of trade instruments to promote infant industries (though there may be fiscal instruments for this purpose), and it has an ample base of skills and institutions. However, it shows technological immaturity in its weak R&D performance and its relatively (in the context of the EC) poor showing in dynamic areas of manufacturing activity. This is again a problem of weak technological tradition, which may have been compounded initially by inadequate ITD financing and insufficient infrastructure support.

- *Korea* built up a deep and diverse industrial structure by virtue of deliberate interventions in the trade and industrial regime, guiding the allocation of industrial investments in particular directions largely under the control of national private firms. These firms imported technology mainly in the form of equipment and licenses, relying relatively little on direct foreign investments. This raised the technological challenge for them significantly, especially because of the pressures on them to be export-oriented very quickly after entering production. As industries entered more complex activities and approached the frontiers of their technologies, local R&D became imperative to keep abreast of world levels of competitiveness. The skill requirements of this effort were met by massive investments in higher-level technical education and by measures to induce firm-level training. Finance requirements were initially left to the existing financial intermediaries, supplemented by a number of instruments to support R&D in approved projects by the *chaebol*. Smaller innovators and other forms of technological effort were not addressed. The S&T infrastructure received a lot of financial and human resources, and seemed to succeed in establishing good linkages with industry. These measures led to spectacular increases in private R&D and the development of a technology "culture" that enabled Korea to achieve its main industrial ambitions. The main gaps that existed were in remedying the financial market failures for smaller innovators and helping the research infrastructure to enter more areas of activity to promote the government's selective industrial strategy. These were the aims of the Bank's main efforts in the technology area.

- *Indonesia* has a much simpler industrial structure than the other countries in the sample, and so has correspondingly simple technological needs. It started with strong protection and inward bias; this has been improved, but significant and haphazard protection still exists and the pace of liberalization is unclear. The continued growth of Indonesian industry and its exposure to world competition require that firms invest in developing better operational capabilities and gain better mastery of the technologies they are using. Indonesian industry remains highly import-dependent for components and equipment as well as for technology and skills, and local firms invest practically nothing in engineering, design, and development. However, some firms are showing increasing mastery of complex process industries as liberalization forces them to invest in more technological learning and operational efficiency. The skill base is small, and the lack of an industrial and research tradition exacerbates the low output of high-level technical manpower. The only concerted technological effort comes from a few PEs (the "strategic industries") that are entering high-technology activities unrelated to the bulk of private industrial activity. The S&T infrastructure is weak and delinked, except for a part that serves the strategic industries. The financing of ITD is nonexistent. Thus, Indonesia's ITD problems cover a wide range, from incentives to skills, finance, information support, and linkage between S&T and industry.

- *Mexico* combines a long history of import substitution with a tradition of heavy reliance on imported technology. Its import substitution was quite successful in creating efficient process and automotive industries, but remained deficient in fostering equipment production. Few local enterprises developed a tradition of design and development over time, and even PEs showed a strong preference for imported equipment and know-how. The extent of local industrial R&D is the lowest of any major industrializing country, and this remains true in a period of rapid liberalization. The skill base is reasonably good. There is large S&T infrastructure that has suffered the usual lack of linkages with production. The financing of technology activity, though addressed by policy makers, has been weak (until the Bank's project). With a more open and competitive regime, the basic problems of Mexican ITD have been the reluctance of firms to invest in deepening their own capabilities and entering the design and development process, and the gaps in the S&T infrastructure.

- *Hungary's* ITD problems in the past decade were primarily related to the incentive framework and the system of ownership, governance, and trade. Despite its substantial and deep industrial base and long tradition of R&D, the hesitant and partial reforms Hungary had undertaken had failed to utilize its technological activity and experience fully to make industry competitive in Western markets. There were also other problems. The base of high-level technical skills was weaker than western European countries. The S&T infrastructure was comprehensive, but had become outdated and underfunded. Nevertheless, some firms retained an autonomous technological tradition and capabilities. At that time, the incentive, governance, and control system was the basic constraint on ITD, with minor ones arising in the financial and infrastructure support areas.

- *India* developed its industrial base behind a set of interventions that had mixed effects, with the costs of inefficiency and technological lags apparently outweighing the benefits of deepening. It pursued a strategy of technological self-reliance more assiduously than most other countries, and invested in a large S&T infrastructure. A broad base of technological capabilities was developed, and there was significant growth of R&D activity. However, the skill base for industry remained relatively small, and distortions in the incentive system meant that technological learning did not lead to fully competitive production or innovative capabilities. The S&T infrastructure was largely delinked from production. Access to foreign technologies was restricted. ITD finance was not well developed. Technological needs of small- and medium-sized firms were not addressed, while R&D by the large-scale private sector was inadequate. A large and generally inefficient public sector engaged in some research, but only a few PEs achieved competitive capabilities. Thus, India's technological problems were wide-ranging, covering all aspects of incentives, capabilities, and institutions.

Note

1. See S. Lall, *Building Industrial Competitiveness in Developing Countries*, Paris: OECD Development Center, 1990.

3. The technology projects

Introduction

This chapter describes the Bank's technology projects in the sample countries in terms of their objectives, design, and performance. These projects addressed the most pressing technological problems of the countries in question, and have to be assessed on whether they identified the problems correctly, devised meaningful responses, and directed resources at the appropriate agents in the most effective manner. However, a Bank technology project is not expected to meet *all* the ITD problems facing a country. It has to be considered in the context of the Bank's broader operations—especially in human resource development—and policy advice that deal with many issues that affect ITD (such as the general trade and industrial policy framework, or the financial or basic education system), but cannot be addressed directly by a technology project. Its evaluation must therefore be based on the awareness the project showed of such broader factors, and the appropriateness of the project's specific objectives and priorities to the policy setting and the immediate technological problems.

The Bank's involvement with industrial technology projects started in the 1970s. The first project was designed for Israel as a component of an industrial development loan in 1975 (Loan 1116-IS). This was the last loan before Israel graduated from the Bank. This component—$5 million—aimed at assisting Israel, through the Office of the Chief Scientist, in its strategy of promoting export-oriented industries based on sophisticated product design and production processes. As stated in the staff appraisal report (SAR): "this strategy requires a high level of research capability closely integrated with sophisticated marketing and commercial skills at the enterprise level. It is based on the conviction in Israel that continuing reliance on foreign investment and licensing to acquire technology and know-how does not generally provide a sufficient competitive edge, and is intended to take advantage of one of Israel's major resources: its wealth of technical talents."Specifically six subprojects had been identified and appraised: (a) three that aimed at developing commercial prototypes of promising developments; (b) two involving applied research at the early stages of development; and (c) a multidisciplinary regional technological institution.

While the Bank's loan constituted only 22 percent of the total R&D outlays, the remaining was expected to come from the sponsors and the government. In order to accelerate the pace of development and commercialization of industrial technology, the government had already proposed to support industrial research through grants to industry and to research institutes for up to 80 percent of the cost of selected projects of "national importance."In the case of this project, the amount of grant element was estimated, on average, at 63 percent of the total R&D expenditures, with the sponsors in effect contributing only 37 percent. There was a firm belief in Israel, with which the Bank concurred, that private enterprises lacked the financial means of investing in potentially profitable innovative projects and this argued for strong and generous government support of R&D activities, even in a highly export-oriented economy.

About the same time that the Israeli project was being prepared, the Bank started work on the design of an industrial technology project for Spain. Already in 1973, an internal report prepared by the Bank had concluded that "especially with respect to Spain's gradual integration with Europe, it is important that appropriate policies and programs are set up that are designed to help adapt Spanish industry to the changing conditions....in order to improve productivity to achieve efficient plants, and to narrow the productivity gap between the Spanish and EEC industries, as well as on the extension of quality control and standardization. The promotion of indigenous industrial research would increase the potentials of Spanish industries in international markets."The first reconnaissance mission for the technology project actually took place in 1973 and two of the authors of the above-mentioned industrial sector studies were on the identification mission. While there were practically no R&D activities in the foreign-dominated industries, the mission was impressed by the relatively serious attention that the chief engineers of the locally owned companies gave to technology and the frustrations they felt that their innovations never saw the light of day.

In preparing these two projects, the Bank gradually conceptualized the rationale for risk sharing by the government on the grounds of externalities and capital-market failures. The two projects demonstrated that even in fast-growing export-oriented industrializing economies such as those of Israel and Spain (both on the threshold of graduation from the Bank) the lack of indigenous R&D activities and the commercialization of R&D results remained impediments to industrial and economic growth. This was the case even though both countries had developed high levels of technical skills and operational technological capabilities. The focus on R&D activities and commercialization resulted from the fact that in both countries a fairly developed technological infrastructure existed when these projects were being designed.

Spain[1]

The staff appraisal report states that the Spanish project was intended to "encourage and increase the quality and quantity of efforts to develop new products and processes, and to bring them to the point of commercial exploitation."These ambitious objectives were set in an economy with a well-established industrial sector that had failed to develop a significant research tradition, though it had managed to build up a heavy industrial sector behind protective barriers and to upgrade its operational capabilities to cope with gradual liberalization. The project was based on a clear recognition that, despite the liberal trading and the technology-import environment, Spanish industry did "very little research, development and engineering of new products,"and that the resulting heavy dependence on foreign sources of technology "limited the ability of Spanish enterprises to export and to compete in foreign markets."The SAR goes on to say that "inertia in Spanish R&D is difficult to overcome without special effort. There is almost no 'habit' of undertaking research and development in Spain."

Thus the problem facing Spain was essentially different from that existing in Israel. In Israel, there existed a thriving habit to undertake R&D work and the amount of R&D expenditures at universities and industrial enterprises had reached around 1.4 percent of GNP by the mid-1970s. Despite this impressive overall effort and the government's policy of encouraging R&D in the private sector through a program of 50/50 matching grants, only about 22 percent of the total R&D expenditure in Israel was in applied research carried out by industry. The government of Israel, therefore, felt that it had to accelerate the pace of development and commercialization of industrial technology by supporting industrial technology development more generously through grants (up to 80 percent) to the selected projects with significant potential payoff.[2] In contrast, one of the most important objectives of the project in Spain was to inculcate the habit (culture) of undertaking R&D activities, especially by the private sector.

The Spanish project saw a role for a new institution that would catalyze the process of R&D by *direct and selective interventions in the process of importing and utilizing technologies*. In this the objectives of the Spanish project were broader and more interventionist (in a liberal market setting) than in subsequent projects. In other words, the market failures addressed were much larger, and there was greater faith in the abilities of governments to intervene effectively. The new institution would take a *direct and active role in the selection, importation, adaptation, development, and utilization of industrial technologies in activities selected for their importance to Spanish competitiveness and export potential.* It was expected that the R&D would take place in enterprises and research institutes (separately and in collaboration), so that linkages would be strengthened. More significantly, the activity would have beneficial spillovers in creating a *research "culture"* in Spanish industry. The main objective was thus based on the reasoning that industry itself could not select areas of future comparative advantage and find the right technologies for those activities, was reluctant to invest in assimilating and adapting those technologies, and was unable to find the finance to develop its own technologies. The market failures thus ranged from those in *resource allocation*, arising from *lack of foresight and information, weak risk bearing capabilities, and possibly externalities*, to the more normal *capital-market and linkage failures*.

The explicit selectivity of the Spanish project and its belief that "correct"incentives were not enough to stimulate the demand for ITD make it unique among the projects reviewed here. Implicitly, the project's objectives were close to what the Korean government (but not the Bank's ITD project in Korea) had achieved by directly intervening in resource allocation and technology imports by its industrial and trade strategies. However, the significant difference was that the project tried to achieve industrial targeting and a dynamizing of the country's R&D culture by setting up a new institution to finance research rather than by intervening in trade and industry. The objective was possibly valid, but if Korea has any lessons to offer, the *means chosen seem rather anemic in relation to the ends*.

The research development and engineering (RD&E) unit to be set up to lead the growth of Spanish ITD, later called the *Centro para el Desarrollo Tecnologico Industrial* (CDTI), was initially to be an autonomous body within the Ministry of Industry. It soon became evident, however, that this did not give CDTI sufficient autonomy and made it impossible to recruit the right quality of staff, take risky decisions, and generally promote ITD effectively. The Bank pressed for a change, and in 1984 the reorganization was effected, giving CDTI the necessary autonomy.

The original design of the project was that CDTI itself would purchase the necessary equipment and take the lead in formulating and implementing research projects. This quickly turned out to be unrealistic. CDTI could not select appropriate research projects for firms and teach them how to do research, and soon it became a more passive financier of industry initiatives. The expectation that an institution like CDTI could change the prevailing research culture of Spanish industry (without any change in the larger incentive regime and in the face of strong international competition with easy access to foreign technologies) was too optimistic, and the institution was not given the policy tools or the skills needed to mount a Korean-style industrial strategy.

The project called for CDTI to support ITD in electronics, mechanical equipment, and food processing, but it quickly had to diversify its activities and enter other industrial fields like chemicals, biotechnology, and energy. In practice, CDTI's financing did not meet the original design expectations: very little of the money went into original research by Spanish firms. Most of the investments were for absorbing and improving imported technologies and a significant part of the borrowing was by foreign affiliates. The objective that CDTI would enter very risky areas and fund individual innovators was also not entirely fulfilled: its lending tended to be conservative and focused on well-established firms.

The project got off to a slow start because of the difficulties in addressing CDTI's autonomy. The matter was not resolved until 1984 when the government finally agreed to pass the necessary legislation. During the seven years up to the end of 1984, CDTI approved 306 projects with partial financing from the Bank loan. The average cost of CDTI projects was $0.51 million, in which CDTI's participation averaged $0.28 million. Of the total, 86 projects had been completed and 40 projects had begun repayment. Few of the projects involved advanced indigenous research. Most were for development and engineering of the existing technologies, either already known in Spain or imported.

Currently CDTI finances two types of projects within Spain. The first is termed a "technology development project,"which is based on funds allocated by the Ministry of Industry, Trade, and Tourism. This type of project deals with research conducted by enterprises in selected sectors and follows the original idea of developing technology in key areas. These projects constitute some 79 percent of CDTI's total commitments until 1990. The second type, termed "projects carried out under agreement,"is financed by the National Scientific and Technological Research Fund. These projects, starting in 1987, deal with pre-commercial joint projects by firms and universities or public research institutes. CDTI has financed 334 projects of this type since 1984, and the total number of projects approved by CDTI has risen from 110 per year in 1986 to 307 per year in 1990. CDTI has also been charged with managing Spain's participation in the European Community projects such as Eureka, Esprit, and BRITE/EURAM.

CDTI has, in recent years, been covering 35 percent of total research costs for technology development projects and 42 percent for projects under agreement. In 1990, the average cost per project for technology development projects including the companies' contribution was $1.8 million. The average cost per project for the joint industry-institute projects was $1.2 million. The total cost of CDTI-financed research projects ($16 million disbursed in 1990), constituted about 10 percent of the Spanish R&D in that year.

Korea

The Bank's first technology project in Korea was the Electronic Technology Project (Loan No. 1676-KO) approved in 1979. The objective of this targeted project was to develop KIET (Korea Institute of Electronic Technology) as a central facility in the semiconductor industry. KIET was expected to provide technological infrastructure of essential production and support services; to assist in the training of technical staff of the industry; to lead industry in acquiring and developing technologies; to carry out RD&E for industry; and to explore market opportunities for the industry abroad. Contrary to expectation, the major companies in Korea started to invest heavily in semiconductor technology and manufacturing and opted for a policy of self-sufficiency in the major services that KIET aimed to supply. With delays in the implementation of this project the government of Korea eventually decided in 1985 to merge KIET with another research institute in telecommunications and form a new institute.

The lesson derived from the Spanish RD&E and the Korean Electronic Technology projects was that targeting is a very difficult proposition if it is to be implemented by public institutions. While the acquisition of semiconductor technology may have been the crowning success of KIET—demonstrating the practicability of obtaining highly sophisticated and proprietary technologies—it was clear that the private sector was not so keen in collaborative efforts of this kind in a highly competitive environment. The Bank used its experience with these two projects in the design of the industrial technology development project in Korea. Thus it insisted on creating an entity that was majority-owned by the private sector and moving away from targeting.

There were three technology development projects in Korea aimed at financing the Korea Technology Development Corporation (KTDC).[3] The main objective of the *first* of these projects was to remedy market failures in the *early stages of financing technical effort*. Conventional sources of finance were not geared to meeting this particular need, with its high risk element. However, the technical effort aimed at included both the import of foreign technology and in-house development work. A secondary objective was for KTDC to "influence and reinforce industry's attitude towards further undertaking of RD&E activities,"using the finance of specific projects as a catalyst to help industry identify promising areas for research and to improve their capabilities to manage and implement R&D projects. Thus, KTDC would also provide information and instruction to firms, thus helping *remedy failures in information markets* for ITD. Finally, KTDC would promote closer links between research institutes and industry by encouraging and financing projects sponsored by the latter and carried out by the former. This would *remedy failures in linkages* between the infrastructure and enterprises.

The *second* KTDC project strengthened these objectives, while assisting KTDC's institutional and skill development, establishing the foundation for the institution's long-term resource base, introducing new instruments, and expanding support to SMEs. The *third* project continued support for KTDC, while adding further financial instruments, strengthening its capacity to deal with riskier projects, and helping start a subsidiary, Korea Technology Investment Corporation (KTIC), to finance "technology start-ups."Over time, it was found that KTDC was providing valuable advice to government agencies in formulating technology policy, and was helping the Ministry of Science and Technology to appraise national R&D projects to be carried out jointly by SMEs and research institutes. Thus, the objectives grew to remedying *failures in institutional skills, providing information for policymakers*, and *delivering technological support to SMEs.*

The progress of the three projects suggested that the original objectives had not been wrong. The main deficiency that they were addressing, capital-market failures, was correctly identified as the main constraint to ITD in Korea at that time. Other deficiencies were also identified, but were assigned lower priority, or else were thought to be dealt with by other policy measures. It is important to note that the projects were *aimed at functional rather than selective interventions*. According to the project SAR, the loans were in fact explicitly aimed to "move Korean industrial policy away from one in which the government takes the lead in 'picking winners' towards one which emphasizes functional interventions in such areas as ITD and development of small and medium industry (SMI) and venture capital, where market imperfections and externalities exist." This objective differs from that adopted in some of the other projects reviewed here, and also from the Bank's own support for the Korea Institute of Electronics Technology (Loan 1676-KO), which was clearly selective in intent.

KTDC was established under the Korea Technology Development Corporation Act promulgated at the end of 1980. The Bank had extensive inputs, through its dialogue with the government of Korea in the formulation of the Act and its associated Presidential Enforcement Decree, which was issued in April 1981. Learning from its experience in Spain and the Electronics Technology Project, the Bank insisted that the legal framework should enable KTDC to operate in an autonomous manner with the efficiency of a private company; to have a strong and independent management; and to have the ability and means to attract and retain staff of high caliber and entrepreneurship.

By the time the first loan was approved in February 1982, KTDC was a functioning concern and much of its procedures were already formulated and in place. Since the Bank was satisfied with the institution's procedures, objectives, and capabilities, it used the loan mainly to provide additional resources and to buttress some institutional aspects that were relatively weak. The first loan therefore had a major component to strengthen KTDC's capabilities in the following ways:

- consulting services to strengthen KTDC's abilities to identify, appraise, negotiate, and supervise RD&E projects, especially those for conditional loans;
- consulting services to help it carry out studies of Korean industrial R&D and areas of potential development;
- visits from experts from other countries' technology financing institutions to exchange experiences;
- training of KTDC staff; and
- purchase of educational materials for use by staff.

The second project continued the emphasis on institutional development. The third went on to introduce new financial instruments (such as leasing and factoring) helping develop capabilities to appraise more complex projects, and to set up a subsidiary (KTIC) to invest in technology start-ups. The lead, in this as in many other aspects of industrial policy, came from the Korean government rather than the Bank, and formed part of a larger strategy that worked extraordinarily well. The details of the projects evolved through consultation between the Bank and KTDC, and seem to have been well conceived.

The Bank's lending for industrial technology in Korea has undoubtedly met with a large measure of success. KTDC has become a very professional and efficient institution, gaining experience and strength with the passage of time. It became a very important instrument for developing technology, especially in the SMI sector. Its current activities are manifold, ranging from financing ITD projects to venture-capital operations, promotion of industrial technology development among SMIs, brokerage services, leasing and factoring, and information services. KTDC has also become an important arm of the government in reviewing national projects and other projects, partially funded by the government, in its efforts to promote cooperative research between public research institutions and industrial firms.

Despite its successful performance, KTDC's record in promoting risk-sharing financing has not been very impressive. Neither has the Bank pursued this matter very vigorously with KTDC, though the Bank made it a specific objective of its third loan. This shortcoming was, to some extent, due to the mix of KTDC's financial resources, some of which were not suited to risk-sharing financing. Nonetheless, it should be noted that this type of financing moved on an upward trend and both KTDC and its subsidiary KTIC expanded their venture-capital activities.

At the end of 1991 KTDC's charter was changed and, since July 1992, it has been the Korea Technology Banking Corporation (KTBC). This action on the part of the Korean government (which had stopped to supply low interest loans to KTDC in the beginning of 1990), was in line with its previously announced intentions. It should, however, be accompanied with sufficient flexibility to allow KTBC to survive in a financial environment that is becoming increasingly competitive. The government's shareholding through the years had dropped to 22 percent, while KTBC's shareholding remained moderately diffused with 163 small- and medium-sized firms owning 13.5 percent of the shares.

Indonesia[4]

The Indonesian project is somewhat unusual in the present context because it was not directed at technological activity per se but at strengthening the skill base for ITD. At the same time it was not an education project in the usual sense. It was explicitly aimed at meeting what the Bank regarded as the critical constraint to ITD in the country—the shortage of professional manpower in science and engineering for which there were insufficient indigenous training facilities. Its broad objective was thus comparable to that of the other projects studied here. The specific objectives were threefold: to strengthen R&D capacity by "developing a nucleus of well-trained Indonesian scientific and technical manpower through programs of study in science and technical fields"; to develop procedures for implementation of the overseas fellowship programs; and to develop relationships between Indonesian and foreign research institutes and universities.

The project identified overseas training as a short-term and cost-effective means of meeting Indonesia's pressing skill needs for absorbing foreign technology, and thus addressed *market failures in local education and training markets*. The incentive framework at the time, while far from ideal, was being reformed. That Indonesia lacked an adequate base of high-level skills for industrial technology was indisputable, and the objective of meeting skill needs of research institutions seemed valid. However, the premise that training high-level manpower for six nonministerial research institutes (LPNDs) under the aegis of the Ministry of Science and Technology as a means of promoting industrial technology development was based on certain implicit assumptions: that the LPNDs were capable of delivering technological assistance to Indonesian industry; that the LPNDs were the most deserving of the S&T institutions in the country; and that industry; was engaged in an active process of technological upgrading and effort into which it wanted inputs from the S&T infrastructure. The first two of these assumptions are questioned in the analysis of project design. The last one needs some discussion here.

The SAR for the project clearly noted that private industry in Indonesia did practically no R&D. As a relatively new sector, with low linkages to the local economy and practically no autonomous design and development capabilities, modern Indonesian industry was heavily dependent of foreign equipment, consultants, and technologies. There was no tradition of long-term technological effort beyond the minimum needed to make technologies operational. This was partly because local skills were deficient, and partly because the S&T infrastructure was ineffective and delinked. However, it is not clear that these were the only, or even the major, constraints of the development of Indonesian ITD. The experiences of the other countries in this sample, with reformed incentive structures and ample supplies of skilled manpower, suggest that there are other factors at work that affect the development of ITD.

There may, however, be greater justification for focusing on skill needs in research institutions in a case like Indonesia. Its ITD at this stage of industrial development should consist of assimilation of imported technologies rather than of more innovative design and development work. This requires fairly routine work that may feed into industrial technology if it is properly conducted and linked to enterprises. However, the institutions selected for assistance were in fact not engaged in this kind of work. They were mainly linked to the "strategic industries" under the control of the Ministry for Research and Technology, which aimed at quantum leaps into high-technology activities and at entering innovation in these activities.

Given the premise that skill constraints were the most binding ones on Indonesian ITD, this project was designed to help skill acquisition in six LPNDs by sending personnel overseas for high-level training. The LPNDs were responsible for the bulk of formal R&D expenditures in Indonesia, and so were ostensibly the right targets for the project. However, the project ignored the fact that they were primarily geared to serving the needs of the strategic industries under the control of their ministry. The strategic industries (ten in total) represented a "big push" strategy of technology advancement in Indonesia. They were aimed at setting up activities in advanced industrial activities, and systematically importing, mastering, and building upon state-of-the-art foreign technologies. They were protected from import and local competition, given soft budgets, and allowed to operate with few linkages to the rest of Indonesian industry. The means by which they would improve industrial technology of the bulk of Indonesian industry was not clear.

While the government's strategy of building up technological capabilities within the selected activities was acceptable in principle, the focus on high technology areas,[5] the lack of linkages of most strategic industries to private industry, and their protected status (and lack of economic accountability) meant that it ran the risk of being extremely wasteful. The project's design seemed to support the belief that such a technological strategy was efficient and desirable for Indonesia. Not only was this unjustifiable, it fed into a process by which scarce skill and training resources were diverted from other, possibly more deserving, institutions that were geared to serving the technological needs of Indonesian industry. More specifically, a range of institutions under the Ministry of Industry—which were poorly equipped, staffed, and financed, and apparently far more relevant to ITD in private industry—were ignored in the project.

The project accepted the "big push" approach to technological development rather than the more modest approach of supporting non-R&D forms of ITD. It helped to reinforce the position of strategic industries. The skills it helped to create are likely to have few benefits to private industry. The industries it does feed into may turn out to be economically inefficient. On these grounds, the design of the Indonesia project seems to be faulty and misdirected. A project for developing skills for ITD would have been much better designed, in Indonesia's case, if it had helped private industry and the supporting infrastructure that could directly feed into its problems of quality, productivity, design, maintenance, and other such mundane issues (see, for example, the provisions of the Mexican project on research centers).

The Overseas Fellowship Program provided for about 1,500 overseas fellowships in mainly physical sciences and engineering fields with a small number of fellowships to be earmarked for related fields such as management and information science, contract and patent law, and statistics. This total of fellowships was to be roughly broken down into 250 in Ph.D. programs, 650 in M.Sc. programs, 300 in B.Sc. programs, and 300 in nondegree training. These general objectives appear to have been realized and by May 1992, some 1,079 fellows had returned to Indonesia out of which 12 percent did not obtain the intended degrees. The remaining fellows were then being supported by the Professional Human Resource Development Project (Loan 3134-IND), which was approved in November 1989.

Mexico[6]

The primary objective of the project was to "help improve the capability of industry (especially private firms) to undertake technological innovation needed to face increasing competition in the context of the government's economic liberalization program."It was thus placed in the context of an incentive framework that was being reformed rapidly in a country with a highly dependent tradition of technology development. The broad objective was to be achieved by improving policy instruments through analysis and studies, a selective strengthening of the S&T infrastructure and the expansion and strengthening of specialized technology financing. The market failures addressed were therefore similar to many of those in the Indian and Korean projects: *capital markets, infrastructure "public goods," linkages,* and *policy information and analysis.* Potential gaps in skill markets were ignored in this project, perhaps in the belief that Mexico's human-capital base was adequate. This may have been true in a general sense, though it is difficult to judge whether this was also true in terms of the specialized high-level skills needed for ITD.

The objectives of the project were based on an analysis of the demand and supply sides of the determinants of Mexican ITD. On the demand side, the SAR identified the legacy of import substitution policies and restraints on inflows of technology and FDI as the main cause of low technological activity in industry. The liberalization of trade, technology, and foreign investment under way was seen as removing all the demand-side constraints to ITD—in the new incentive framework Mexican industrial enterprises would, if supported by supply-side measures, themselves come forward to invest in R&D. In this respect, there are important differences from the Spanish project. The Spanish project was based on the belief that Spain would not be able to maintain export growth without sustained increases in local R&D investments. It argued that continued reliance on technology imports would not allow the country to develop industrially in a liberal trading environment, and that special measures were needed to catalyze the process. The Mexican project, on the other hand, believed that liberal incentives and access to foreign technologies were all that was needed to dynamize the demand side of ITD.

This analysis may have been oversimplified. Much of the base of competitive capabilities built up in Mexico, that then led the export surge after liberalization, had been developed under the earlier import-substitution regime. Liberalization was clearly necessary in order to remove the distortions that held back the exploitation of these capabilities and impeded the development of new capabilities. Access to foreign technologies may not have been fully liberal, and may have contributed to technological stagnation. However, Mexico had the largest imports of technology of the NIEs, certainly much larger than Korea, which also pursued import substitution policies. The fact that these technological capabilities in Mexico had not been *deepened* had less to do with restrictions on access to foreign technology than with the industrial sector's traditional dependence on imported technologies and the underdeveloped local equipment manufacturing sector. It is doubtful, therefore, if freer access to foreign technologies per se would boost indigenous R&D effort in much of industry. Some firms that had a research tradition would utilize the liberalization to invest more in research, but the bulk of industry could become more dependent on imported technologies to meet the threat of world competition.

On the supply side, the objective of remedying market failures was justifiable per se. The project had five specific objectives:

- analysis of ITD issues to help the government develop appropriate policies and instruments (financed by the government of Mexico);
- strengthening the technology infrastructure through selected restructured R&D centers, with private-sector ownership participation;
- study for strengthening metrology services;
- specialized financing for ITD via the National Fund for Industrial Equipment (FONEI); and
- institutional strengthening of FONEI.

The bulk of the project ($37.1 million of the total of $48 million) was for financing ITD. Industrial technology development was defined broadly, to include all efforts to assimilate and improve on foreign technologies, upgrade productivity, and develop new products. In this it was similar to the Korean projects, except that the context of local R&D effort was entirely different. In Korea the projects were to add to a process that was already vibrant and dynamic; in Mexico it was to stimulate and build up an essentially marginal activity. It was a very ambitious objective.

The ITD studies were to be carried out by the Secretary of Commerce and Industrial Development (SECOFI), and were intended to analyze the determinants of innovative behavior and the policy framework for promoting ITD. They were to draw on the experience of other countries. However, the initial intention to use these studies in policy formulation was diluted as the government's policy direction changed.

The restructuring of the National Program of Science and Technology (CONACYT) research centers was to start with four selected institutes[7] (of a total of eight), and was to involve an element of privatization along with the investment of funds. The centers would use the investments to re-equip and improve their capabilities to meet the needs of industrial firms in terms of product development, design, technical assistance, quality control, and technological information. The beneficiaries were expected to be mainly SMEs, who lacked their own technical facilities and whose technological upgrading would, in turn, benefit large enterprises that purchased their products.

The ownership of each of the selected centers would be changed, with part of the equity held by CONACYT and part by private enterprises (it was hoped that the dominant share would be privately held). The enterprises were expected to play an active role in the management of the centers, to make them more responsive to industrial needs. The Bank project would lend, through FONEI, up to 100 percent of the money to take equity shares in private enterprises. The total investment in the four centers was estimated at $16.8 million, of which the Bank would finance $8.2 million.

This seemed an imaginative and appealing design for reforming and reorienting CONACYT R&D institutions.

It was not clear from the project documents, however, which private enterprises were expected to play the "senior partner"role in the reformed centers. The SAR did not discuss which firms would have the desire to take on this sort of financial responsibility or the skills to participate in the running of an essentially infrastructure service. Large firms with the financial and human resources may not have been interested, because the centers were aimed at SMEs, while the latter may not have had the desire or resources to participate. It also raised the question of whether private ownership in the provision of services with strong "public goods"characteristics was necessarily a desirable objective, or whether responsiveness to industrial needs may have been achievable by other incentive and institutional measures.

The study of the metrology infrastructure was to be conducted by SECOFI with the help of foreign consultants. This would address a vital need of Mexican industry, which lacked an institution for the calibration of measuring instruments.

The bulk of the loan was intended for ITD financing, through commercial banks, by FONEI. The financing was intended particularly for commercializing locally developed technologies, though the import and assimilation of imported technologies was also included, and would cover research centers as well as engineering firms and industrial enterprises. It would consist of a mixture of loans, grants, conditional loans, and equity (the last would be new, to be tried on a pilot basis). The government initially agreed to strengthen FONEI's financial base so that it could adequately provide the subsidy element. It was expected that FONEI's financing would grow by *45 percent per annum* during 1985–88.

The design of the project altered soon after its launch, because FONEI was merged into a national financiers company (NAFINSA) in 1988 and some of these financial aspects were changed. The government asked that the grant and subsidy element of the ITD financing be reduced as part of its general move away from interventions in the market. The grant and guarantee elements were to be replaced by greater equity participation by NAFINSA, and subsidies were to be completely phased out by 1990.

The design of this component of the project, both original and revised, was based on rather optimistic expectations of the demand for financing by Mexican enterprises for conducting their own research and development (importing technologies was also included, but was implicitly regarded as a second-best form of ITD). Given the poor record of innovation by the bulk of Mexican industry, this was presumably based on demand for innovation expected to be created by the liberalization and the availability of technology finance from the project. As noted earlier, this was an overly simple view of the determinants of technological activity in Mexico, though it seemed to be one to which the government increasingly subscribed. The revised design, removing all the subsidy elements from ITD financing, seemed to assume that there were no information or other market failures for local firms in undertaking R&D activity. The possibility of channeling resources into activities selected for their externalities or future comparative advantage was not considered. Nor was the possibility that the liberalization would raise the demand for more imported technologies rather than for local innovative effort. The results of the project suggest that these factors should have been taken into account.

The pattern of technology lending by NAFINSA proved very erratic. The large increase in technology lending expected in 1985–88 did not materialize and in any case the sums involved were very modest (1984: $10.3 million, 1985: $20.1 million, 1986: $18.7 million, 1987: $21.3 million, and 1988: $11.8 million in current US dollars). Such lending lost more ground in 1989 and only recovered somewhat in 1990. It appears that many of the projects were for upgrading productivity rather than for innovation, and that most of the innovative R&D was undertaken by the larger groups (or by smaller technology groups set up by them). There were, however, few cases of innovative activity in smaller companies, many in the software area, where small-size and low-cost engineering manpower provided an advantage to Mexican firms in exporting systems to the US.

The selective strengthening of infrastructure through the restructuring and privatization of four CONACYT institutions has had very limited achievement. Of the four preselected R&D institutions that were earmarked for restructuring, the pharmaceutical center was the first to be privatized. This was achieved by the end of 1987, but the Mexican Secretariat of Planning and Budget (SPP) decided to keep the other R&D centers in the public sector. Despite the unusual assistance envisaged in the project—FONEI initially lending up to 100 percent of the funds needed by eligible industrial enterprises to invest in the restructured R&D centers, at an interest rate of not less than the average cost of funds to the banking system—there was little enthusiasm by the private sector to participate in the scheme.

In early 1988, just as the technology policy analysis study was being reviewed and discussed, SPP initiated a second effort (supported by funds from the project) in formulating an industrial technology policy. This later study was completed by the end of 1988 and formed the basis for the National Program of Science and Technology Modernization in 1990–94, which provided for an increased commitment of resources to support the science and technology program and to elicit greater participation from the private sector. In brief, CONACYT was restructured and trimmed, and placed under the Ministry of Education (rather than Planning). Funding for basic scientific research was increased (but with allocations determined by competitive bids rather than government priorities). The public research centers were rationalized, made more service-oriented, and made to earn a larger proportion of their revenues; the private sector was to take a greater role in operating and financing them. The worst performing centers were to be shut down (as in pharmaceuticals and food in Chihuahua). Four Presidential Funds were created for improving the science institutions, repatriating Mexican scientists, for endowing Chairs of Excellence, and for funding equipment purchase for ITD activities. A nonpresidential fund was set up to fund ITD projects by private industry at concessional rates of interest. Incubators were to be set up to encourage the commercialization of academic research. The metrology center was to be set up, and quality assurance and standards were to be improved. Intellectual property protection was to be strengthened. Access to foreign technologies and the inflow of foreign direct investment were to be encouraged.

It is too early to comment on the effects of the new policy framework for ITD in Mexico, but it appears that the thrust of the initiatives is in the right direction. The incentive framework for ITD has improved, though it is not clear whether the liberalization will stimulate upgrading via further ITD or the import of technology. The reduction in the scope of infant industry promotion may channel future ITD in less risky and less dynamic areas of industrial activity. In general, it does not appear that any catalyst has been planted that may change the traditional attitudes of Mexican private industry towards R&D. This does not mean that improvements in the technology support services will not be valuable in raising the efficiency and competitiveness of industry—most of them are vital current inputs into the production process. However, whether or not such improvements will lead to greater innovative activity is not clear from the evidence at hand.

Hungary[8]

Because of the socialist setting, the Bank's technology project in Hungary was bound to have different objectives from the others in the sample. Nevertheless, the stated objectives were not very different. The Hungary project sought to "improve the capability of Hungarian industry to undertake and sustain TD necessary to meet the national objectives of increased productivity and international competitiveness in the context of the government's economic reform program."

Though this seems to have similarities to the Mexican project, which was also located in the context of a reform program, there are many differences between them. On the one hand, Hungary already had a mature industrial sector (the longest-established in the sample), with a strong technological tradition, a capable capital-goods sector (though one that had been forced to specialize according to lines laid down by the CMEA), and a diverse S&T infrastructure. On the other hand, the ownership and incentive structures were grossly distorted, and many of the market institutions (especially in the financial sector) were missing. Technology imports and FDI were much smaller than almost all the countries in the sample, with the possible exception of India.

The liberalization envisaged in Hungary at that point was very limited compared to that in Mexico. It consisted of allowing greater competition and enterprise autonomy, imposing greater financial discipline, encouraging more trade, reforming banking, allowing state enterprises to exit, introducing new laws on enterprises, and seeking more FDI. In effect, these were moves to introduce more market forces within the socialist system of ownership, and to start developing some of the relevant institutions. They were important reforms in the Hungarian context, but very tame compared to the usual structural adjustment programs in many developing countries. It was the 1990 reforms after the political shift that marked a real liberalization, but these came after the project was started.

In the context of the more modest reforms under way in 1988, the technology project's objectives were fivefold:

- Improve the S&T infrastructure, especially in computer applications and software;
- Improve production in industries selected for their spread effects on other industries;
- Increase the commercial orientation of R&D activities;
- Develop activities that could become internationally competitive; and
- Develop and strengthen institutional and financing mechanisms for ITD.

These objectives had certain standard components addressed to market failures in infrastructure, capital markets, and training needs. They also had some elements that were less standard, with similarities to the Bank's first technology project in Spain: the *targeting* of particular industrial and infrastructural activities that were likely to have beneficial spillover effects and to dynamize Hungary's comparative advantage. The project argued that Hungary's R&D resources were being "spread too thin," and that interventions to guide them into particular directions would increase the impact of the technology project. The rationale for directing R&D was slightly different from that advanced in Spain. In the latter, enterprises did not have a research culture and were considered unable to select and develop technologies appropriate to long-term comparative advantage. In Hungary, the research habit existed, but market forces had a limited impact on resource allocation, and the existing method of R&D spending spread resources ineffectively.

It was clearly acknowledged by the project that, despite the significant proportion of GDP devoted to R&D, the past incentive structure had negative effects on Hungarian ITD. Was it right to seek to upgrade technological activity within the context of ownership and distorted industrial structures? It seemed likely that the enterprises directly benefiting from the project would gain in productivity and competitiveness, despite the incentive problems. However, it was unlikely that in that setting, with restricted domestic and foreign competition, overintegration of production, lack of accountability and governance, and so on, this would spark off a sustained process of ITD. Thus, the objectives of the project seemed unrealistic without more drastic reforms than appeared feasible at that time.

The Hungarian project had three components: investments in "commercially oriented"subprojects, two investments in infrastructure institutions, and training. The *first component*, constituting the bulk of the project (92 percent of the loan), had two subcomponents. The first subcomponent dealt with infrastructure to support commercial R&D. There were three projects here: the production of special-purpose printed circuit boards to enable closer linkages between designers and users of tools, models, and instruments for R&D work; the supply of imported R&D instruments for rent; and the setting up of an "innovation park"for researchers from the Budapest Technical University.

The second subcomponent dealt with the introduction of new technology into productive enterprises selected for their externalities and competitive potential. Three projects had been selected for preappraisal. These included CAD/CAM (computer-assisted design and manufacturing) services for SMEs and two automation projects for upgrading process control equipment in manufacturing and process industries. The third subcomponent consisted of two subprojects in computer software development. Future projects would be appraised on criteria of introducing new technologies, strengthening the R&D infrastructure, and upgrading the software industry. These components were themselves part of the government's medium-range plan for technology, launched a short period earlier to concentrate the country's technological resources on selected priorities. This plan had twelve programs to be financed jointly by the government and enterprises (divided 47 percent-53 percent). The Bank thus picked up on the evaluation and priorities of the Hungarians themselves, with the common perception that automation and software had the most to offer industry in terms of productivity returns to a limited investment.

The *second main component* of the project (7 percent of the total) consisted of two preappraised investments in noncommercial state-owned infrastructure institutions, the Center for Metrology, and a set of nine Quality Control Institutes. The skills for testing and calibration were present, but the equipment was obsolete. The explicit intention was to improve quality control and certification for Western export markets. The *third component* of the project (1 percent) was for technical assistance and training to banks, enterprises, institutes, and government officials in technology management and appraisal, and for two studies on policy planning. Both components seemed sensible and coherent.

Given that the incentive structure in Hungary was distorted, and that no existing institutions could allocate resources efficiently, the project was designed to direct resources into areas of greatest economic significance. The Bank accepted the government's priorities in technology upgrading and the proposition that scarce technological resources had to be carefully marshalled and used in a few areas that could yield the greatest benefits to competitiveness. It also accepted that R&D was being "spread too thin" and, despite its high level, was not allowing industry to keep up technologically. Thus, the project made a case for guiding the strong technological efforts that existed in Hungarian enterprises.

The project was overtaken by events shortly after coming to effect. Still by mid-1989 the implementation of many of the subcomponents had started. Subloan agreements had been signed for the three projects constituting the R&D infrastructure, namely: the facility to produce the special-purpose printed circuit boards, the entity to effect instrument rental, and the Innovation Park. Of the other five preappraisal projects that were supposed to introduce new technology into industry, four opted out in view of the uncertainties created by the new economic environment. Instead, industrial entities with fairly good technology such as the pharmaceutical enterprises chose to meet the new competitive environment with intensified R&D efforts and they, therefore, joined the project. In fact by early 1992, the number of these new beneficiaries had reached nine, with others awaiting the result of their application.

By the end of 1992 disbursement remained somewhat behind schedule at around 52 percent. All subcomponents dealing with the Metrological Center and the Quality Control Institutes had been implemented. Although the Industrial Automation I subproject (designed to upgrade the capability for production of automated control equipment for manufacturing industry) had been successfully completed and design laboratory was fully operational, the company was running into financial problems due to the loss of its CMEA markets and the weakness of its domestic market. The instrument rental and the printed circuit board subprojects were also facing financial difficulties. The former enterprise is being privatized and the latter is expecting better capacity utilization through higher export sales.

On the strategic approach, the objective of targeting particular technologies was unusual in the context of the Bank's approach to ITD in the 1980s. Only the Spanish project of 1977 had espoused similar targeting. In general, the strategic element was reflected in the focus on computer technologies as the means of promoting ITD. It is possible that the Hungarian project was so designed because of the weaknesses of market forces there, and it was thought that in this setting some of direction of investment was justified. However, given the distortions that existed in the economy, it is not clear that such targeting would have given the desired results.

The objectives of the Hungarian project thus have a mixture of strengths and weaknesses. The strengths are the attempts to direct resources at selected areas to maximize the impact of the loan, and to meet the usual market failures in finance and infrastructure. The weak ones are the acceptance of the distortions in the industrial and incentive structures, within which the project was bound to have more limited benefits than envisaged. In this sense, the project overestimated the scope of the reforms underway at the time, and so failed to address the most pressing ITD needs of the country.

This raises a general question on the design of technology projects. Is it the case that other countries, with less-developed industrial structures and little tradition of R&D but with market economies and institutions, are better at allocating technological resources than Hungary? Or are there market failures, apart from those caused by mistaken government interventions, that lead to underinvestment in technological effort and its diversion into wrong activities?

The evidence on the sample countries suggests that there do exist market failures that may lead to misallocation of technological resources and inadequate ITD. These market failures arise from the lack of information on the technological development process, the externalities that are inherent in creating technical knowledge and skills, and the costs of investing in learning technologies that have already been fully mastered elsewhere. It is possible, therefore, that the level of technological investments is socially suboptimal, that it is not undertaken in areas that seem to involve high learning costs. This is the rationale for policy interventions to stimulate and guide technological effort.

The second question is whether the Hungary project itself took sufficient account of the structural constraints (apart from inadequate ITD) that held back industrial competitiveness. If these constraints were more binding than those of technology, the project could not be expected to have the desired impact on productivity and competitiveness. The evidence suggests that this was in fact the case.

India[9]

The general objective of the project was to "boost technology acquisition, development, and commercialization in India,"which was to be addressed by three means. These were to provide finance for ITD (*remedy capital-market failures*), improve the S&T institutions and their linkages with industry (*provision of infrastructural "public goods"and remedy linkage failures*), and provide quick access to imported technologies (*overcome failures created by government import and technology restrictions*). In addition, these components would be supported by technical assistance and studies. The project was based on a full awareness of the distortions that existed in the incentive framework for ITD in India, and aimed to support industry in a period of liberalization that was then underway. It drew upon studies of industrial regulations and technology policies in India done three years earlier by the Bank, though it did not try to incorporate all the latter's recommendations into the design of the project.

The project was clearly not intended to remedy the deficiencies in the broader incentive framework. Its own objectives were to promote *functional interventions to remedy the market failures in capital markets, institutions, and access to foreign technologies* noted above. The selection of the beneficiaries of the loan was to be left to the financial institutions that were to deal with the venture-capital element, to the Industrial Credit and Investment Corporation of India (ICICI) for the S&T institutions, and to the government for the technology-import financing (through the Technical Development Fund). The bulk of the funding was directed to the Technical Development Fund, which was to receive $100 million of the total. Next came the S&T infrastructure component, which was to get $55 million, divided between $40 million for interest-free loans to institutions for equipment and so on, and $15 million for a Sponsored R&D Promotion Fund (also to be administered by the ICICI) that would finance loans to industry to cover up to one-half of the cost of research projects sponsored by industry at the research institutes. The venture-capital component was to receive $45 million to fund four schemes to help enterprises develop and commercialize innovative products and processes. Thus, the "revealed objectives"of the India project were to provide functional support for technology imports, strengthen the S&T infrastructure and make it more relevant to industry, and promote innovation financing.

The objective of boosting technology acquisition, development, and commercialization in India was addressed by three components. None of them dealt directly with R&D by large established business houses in the private sector, perhaps on the assumption that they were financially and otherwise well-equipped to deal with their needs. The first component of the project dealt with *venture-capital financing*. This constituted $45 million to be re-lent by the government to four financial institutions to invest in the equity of new venture-capital funds (VCFs). Each VCF would also raise funds from other local and foreign sources. The bulk of the funds ($20 million) would go to ICICI, with another $13.5 million to be shared by three other banks, and the balance of $11.5 million to be given when the first allocation was used up. Experienced staff would be provided by each of the banks. The final beneficiaries would presumably be innovative small- and medium-sized firms that had difficulties in raising other forms of finance. The design of this component was sound, though the projection of the uptake turned out to be overoptimistic.

The second component dealt with *S&T institutions*. Of the total of $50 million allocated, $40 million would be in the form of loans to 12 to 15 institutions, including the Bureau of Indian Standards, to import equipment, set up common R&D facilities to be shared with industry, pay for technology collaborations abroad, train and exchange staff, and upgrade management skills. Six institutions had been preselected including the Standards Bureau and a private R&D institute. The projects would be monitored by ICICI, using criteria of cost recovery, revenue generation, productivity, and licenses sold. Future loans would be made by ICICI. The idea of loan finance rather than grants for the S&T institutions was new to India, and fitted in with the government's plans to overhaul these institutions and make them earn more of their revenue from industry. The timing and design seemed appropriate, suited to making the institutes more service-oriented, and geared to improving their productivity, capabilities, and management skills. Using ICICI as the monitoring agency would introduce a welcome business orientation into the effort.

The remaining $15 million of this component was to go into the *Sponsored R&D Promotion Program*, a pilot effort to stimulate industrial demand for the services of the research institutes. The projects promoted would be carried out entirely by the institutes or jointly by them and enterprises, with the project funds (administered by ICICI) given as conditional loans for up to half the value of the projects. The firms aimed at would be of all sizes, but presumably the large ones would be more able to take advantage of this facility. The sponsors would have a commitment to the research project, while the conditional loan component would act as an incentive to enterprises to enter into this arrangement (if successful, however, the loans would be repaid at market rates of interest). Again, the choice of ICICI as the administering agency seemed apt because of its extensive contacts with industry and its ability to reach medium-sized enterprises. This element of the project seems imaginatively designed.

The third component of the project was the *Technical Development Fund* (TDF). The bulk of the project funds ($100 million) was destined for the TDF, which had been in existence since 1976. The intention was to provide resources for the rapid import of embodied and disembodied technology for "upgrading or product diversification involving the introduction of new and more sophisticated products."Before the inception of this project, the TDF was constrained by various rules. These were reformed, and the project considerably improved its scope and functioning. The main recipients of this component were expected to be SMEs, who would be able to obtain rupee loans at commercial rates to finance the imports. The design of the TDF component drew upon the ICICI's "Productivity Fund,"also financed by the World Bank, which was regarded as a great success.

The design of the TDF was specifically based on the constraints in the Indian technology import regime, and it had strictly limited aims. It simply intended to speed up access to financing for foreign technology, but not to help technology importers in other ways. It did not seek to give technical assistance or information to SMEs on sources, prices, or conditions for technology imports. If it had, its utility may have been greater. Apart from this, the component seemed appropriate to meet a particular need of the time.

The Industrial Technology Development Project is proceeding well. During 1991, the venture-capital financing lagged behind schedule in the three active financial institutions and the fourth, the Andhra Pradesh Industrial Development Corporation, had still not resolved its financial problems. The project expectations regarding demand for venture-capital funds was proving to be somewhat overoptimistic. The largest venture-capital company, the Technology Development and Information Company of India, had launched a second fund (Rupees 1 billion) with money from the Bank's technology project.

This would be the first time that the Indian technology institutions had received loans rather than grants. This arrangement was seen to complement the government's efforts to reform the technology institutions. The government had already launched a major effort to change the Council for Scientific and Industrial Research's culture in order to increase its financial independence and linkages with industry. There were indications that these efforts had been productive. The National Chemical Laboratory's (NCL) earnings had gone up in 1991–92, accounting for 50 percent of the grants coming from the government. Relationships with the ICICI were excellent and the institute had been able to commercialize some technologies through the venture-capital route. Close working relationships had been established with several private industry research units. It appears that NCL is not an isolated case. However, as far as the TDF is concerned, the recent liberalization by the government of India has completely superseded its regulations, and the new technology import regime has led to more expeditious approval and disbursement of funds.

Final evaluation

At the time of writing this study, in addition to the project in Spain and two earlier projects in Korea, the third project in Korea and the science and technology project in Indonesia have closed and their project completion reports are under preparation. The technology development projects in Mexico and Hungary will be completed and closed during 1993–94. Given the relative newness of the project in India, it is likely to be ongoing for some time.

The main objectives of the projects are shown in summary form in Table 3.1. It is evident that despite a diversity of objectives there are many common elements in the projects. The ones appearing in most projects are financing ITD activity and strengthening S&T institutions, with improvements in research institutes and industry close behind. Other objectives are more peripheral. Skill creation specifically for ITD is the primary objective of only one project (in Indonesia); the others only provide for some minor training to institutions that deal with technology rather than technical training as such. Bank projects in education and training normally come under the purview of education rather than technology, even if they deal with industry-related skills. This may result in certain aspects of ITD skill creation being neglected, a weakness resulting from the way in which the Bank divides its functions (this will be taken up in the next chapter). Improving access to foreign technologies is a specific objective only in the India project. Providing

TABLE 3.1: OBJECTIVES OF TECHNOLOGY PROJECTS IN SAMPLE

	Spain	*Korea (only Korea Technology Development Corporation projects)*	*Indonesia (S&T training project)*	*Mexico*	*Hungary*	*India*
Skills for ITD	—	Training for KTDC staff to appraise and manage technology finance. Appraisal procedures to improve R&D management by firms.	Primary objective to provide overseas training for S&T professionals. Also to develop skills for implementing fellowship programs.	Training for financial intermediaries to provide technical finance.	Technical assistance to train staff of enterprises to manage R&D, and to banks and government agencies to deal with technology.	—
Finance for ITD activity	Create new financing institution to take direct role in selecting, importing, developing, and diffusing technology in selected areas. Would commission R&D in selected firms and research institutions, and "teach" firms value of in-house R&D.	Primary objective to provide venture-capital and new financing instruments for technology import and R&D. Establish long-term financial base for KTDC. Later to provide support for finance of SMEs and "technology start-ups."	—	Finance (by mixture of grants, loans, equity, conditional loans) firms and research institutions to commercialize local technologies, undertake ITD to absorb, improve foreign technologies.	Finance introduction of new, imported technology to firms selected for spillovers and potential competitiveness. Finance production of printed circuit boards.	Venture-capital support through four financial institutions.
Strengthen S&T institutions	—	—	Training for personnel from six nonministerial government institutes under Ministry of Research and Technology. Develop collaborative relationships between local and foreign universities and research institutes.	Finance research institutions as above. Restructure research centers financially, with private-sector participation. Invest in new equipment. Fund study of proposed metrology center.	Grants to Metrology Center and nine Quality Control Institutes to modernize equipment. Import R&D instruments for rental. Set up innovation park for academic researchers.	Loan finance to 12–15 technology institutions for equipment, collaborations, training programs, management upgrading, and so on.

Strengthen research institute-industry linkages	Promote and fund collaborative R&D between industry and research institutions, as above.	Finance projects sponsored by industry at research institutions. Bring together researchers and firms.	—	Private-sector involvement in research institutions' finance and management.	—	Conditional loans to industrial firms to meet part of cost of sponsored research at universities and research institutes.
Improve access to foreign technologies	—	—	—	—	—	Finance for Technical Development Fund, to provide quick access to imports of equipment and technology, especially by SMEs.
Information and policy advice	—	Reinforce industry attitudes to R&D. Inform on technology trends, market prospects. Advise government on technology policy.	—	Analyze ITD to help government with technology policy formulation.	Conduct two studies on technology policy.	—

policy analysis and information to the government appears in three cases, but not as an important part of the total project.

The underlying aim of all ITD projects is to strengthen the competitiveness and productivity of the industrial sector. This is based on two general premises, articulated in most of the project documents. The first is that some technological capabilities are essential to achieving world levels of efficiency at all levels of industrial development, but that as the industrial structure grows more complex a developing country has to deepen its capabilities. In particular, it has to invest in design and development capabilities to absorb and build upon more advanced imported technologies. The second is that there are market failures in the acquisition of technological capabilities, which have to be addressed by policy instruments. These are broadly valid premises, but there are certain points about the Bank's approach that are further analyzed in Chapter 4.

The specific objectives of the projects were to remedy the most pressing constraints to ITD identified in the sample countries. These constraints differed according to the level of industrial development, the policy setting, the human and other resources available, and the nature and relevance of the S&T infrastructure. The Bank's perceptions of these constraints informed the objectives set out for each of the projects, but the response in terms of the design of interventions differed.

The nature of industrial technology development projects makes them difficult to conceptualize, design, and appraise even under the most conducive of environments. It requires lengthy and laborious consensus-building negotiations, often with the need to construct alliances. In many instances Bank staff have been the intellectual force behind the idea, in search of knowledgeable, like-minded, and willing interlocutors in the borrowing countries. Because in most cases, new financial entities need to be set up, Bank staff have had to satisfy themselves with the quality of management of such new enterprises. Often, they faced recalcitrance on the part of the staff of R&D and scientific institutions whose indifferent attitudes could not be easily altered. In practice, the expertise in this line of activity in the Bank is too narrowly held by a small number of specialists who have designed and implemented industrial technology development projects, starting with the first loan component in Israel.

Notes

1. Industrial Research, Development, and Engineering (IRDE) Project, 1977, for $18 million.

2. Appraisal of an Industrial Development Project in Israel, Loan No. 1116-IS, 1975.

3. These Technology Development Projects were in 1982, 1984, and 1988, each for $50 million. It should be noted that there are a number of other Bank projects in Korea with technology components that are not considered here.

4. Science and Technology Training Project, 1985, for $93 million equivalent.

5. Like aircraft design and manufacture, armaments, ships, telecommunications, heavy equipment, diesel engines, and so on.

6. Industrial Technology Development Project, 1986, for $48 million.

7. These R&D centers were in pharmaceuticals, agroindustry and biotechnology, metalworking, and chemicals.

8. Technology Development Project, 1988, for $50 million.

9. Industrial Technology Development Project, 1989, for a total of $200 million, made up of a loan of $145 million and a development credit of $55 million equivalent.

4. Assessment, lessons learned, and recommendations

Introduction

Technology projects have played an increasing role in the Bank's operations affecting the industrial sector. Since the early 1970s, the Bank has made a total of 75 loans with explicit science and technology objectives, of which 32 were for higher education, 13 for industry and technology, and 30 for infrastructure and energy. Nearly 85 percent of the projects in the category of industry and technology have been initiated since 1980, and almost 70 percent since 1985. It appears that "over this period both the Bank and developing countries have become increasingly aware of the critical role of science and technology in national development" (project appraisal report). Of these 13 industry and technology projects, eight were in Asia, four in the Middle East and North Africa, and one was in Latin America.

Investment projects, especially those in productive fields, have been a major vehicle for technology transfer and development. Bank lending for industrial projects has normally included imports of licensed technology, advice and information from consultants and equipment manufacturers, and service from equipment and component suppliers. This has usually been accompanied by skills training and a host of other activities that have characterized efficient import of new technology. Though mostly project specific, these efforts have all helped assist the industrial technological development of beneficiary entities, while in some cases the benefits have gone beyond the particular project. In rare instances, the industrial projects have assisted the development of new technology as a part of the project.[1]

Assessment

The need for ITD is clearly and forcefully stated in nearly all the project documents. In general, it is argued that the need to make existing industries competitive and to develop new sources of comparative advantage in manufacturing both need investments in technology development. The perception is that:

- technological activity is a driving force in industrial development, productivity, and competitiveness in developing countries;
- it is a purposive activity that does not result automatically from a passive learning process, and requires enterprises to invest in specific areas like training, information collection, engineering, design, and experimentation;
- it involves the interaction between individual enterprises and an infrastructure of science and technology institutions that provide certain services with "public goods" characteristics; and

- there is a need to deepen technological capabilities with industrial development.

The need for ITD is seen to exist at all levels of industrial development, but the content of ITD varies at each level. At low levels, the most important need is to master the relatively simple technologies that have been imported, to achieve world standards of quality and competitiveness. This need for mastery persists through higher levels of industrial development, but the technologies concerned become more complex, larger scale, and more demanding of specialized skills and knowledge. All the project documents related to the technology loans accept that such operational capabilities may not be easy to acquire, and may need policy support.

At the same time, the ITD projects suggest that the need for technological deepening, a greater understanding of the technology itself (the know-why), grows with industrial development. The technology literature suggests that this is correct. The lack of advanced capabilities holds back not just the ability of local firms to diversify, diffuse technology, and reap the externalities that arise from technological activity, but also their ability to absorb more sophisticated technologies from abroad. R&D serves as much to keep up with technical progress as to generate innovations.[2] Both aspects of R&D are essential ingredients of industrial competitiveness in the advanced industrial countries, while in the developing countries the imitative, absorptive, and monitoring functions of R&D are predominant. However, technological deepening may not follow automatically from the development of operational capabilities. These essential features of the ITD process are clearly understood by the Bank.

There appears to be a broad agreement in all the Bank's technology projects on the proactive role of government in strengthening the supply side of ITD. The Bank accepts that there are widespread market failures in the supply of skills, finance, information, standards, and so on. It has little problem in accepting market failures because all developed industrial countries have, over a long period of time, invested in setting up specific mechanisms and institutions to provide for education, training, technology finance, science infrastructure, and research institutions. It further accepts the need for government intervention on account of the "public goods" nature of ITD efforts and their externalities. Despite this, the Bank shies away from taking the argument to its logical conclusion by accepting that there may be a very good case for selective intervention in exploiting these externalities. There may also be a case that scarce ITD resources should be used in activities with the most learning and spillover potential.

There is no generic design for the ITD projects. Each must depend on the country's industrialization strategy, stage of development, and other country-specific factors. It is, however, very important that there be an integrated approach to the design of an ITD program. Such a program should clearly define the objectives and set out all the actions that are needed to achieve the objectives. For example, if the program aims at enhancing the competitiveness of existing industries based on imported technology, then its design will be somewhat different from one that aims at improving, deepening, and developing technology. Once the elements of a program in terms of capability and institutional development are known, then it can be decided whether all issues are to be addressed by one or many projects and in what order. It could well be that the Bank is satisfied that components of the integrated program are being adequately and satisfactorily taken care of by other loans or by other entities. In short, there has to be a clear integrated program and confidence that all its components are being addressed.

A strategy of developing technological capability needs to be a part of a broader industrial strategy aimed at industrial development and international competitiveness. As pointed out in the 1992 OED study of World Bank support for industrialization, the Bank has been a creditable and effective proponent of trade and industrial policy reform but has failed to develop an integrated approach in order to build up capabilities that are necessary for long-term industrial development in the developing countries. In the words of that report:

> *In principle it is not a very large shift for the Bank to include, in its analysis of industrialization, the interplay of incentives with skills, technology and institutions. Its analysis of incentives, based on restoring market efficiency, remains the same, but it is located in a more comprehensive framework where incentives do not "do all the work." The analysis directly covers such structural factors as investment capabilities, skills of various kinds, technological effort and the development of institutional structures, so that the Bank can evaluate and devise methods to help the "supply response." Taking all these factors into account can produce a major change of emphasis and content in the Bank's analysis of trade and industrial policy. The phasing, content and thrust of liberalization and structural adjustment programs would change, and would take more account of the industrial structure, skill endowments, technological and other features of each country. The design of sectoral programs and projects would also be more realistic and comprehensive.*

Incentives

The Bank's decision to undertake ITD projects, and their specific design, depends strongly on its reading of the incentive regime in each country. There is a clear awareness that the incentive framework has a critical impact on the "demand" side of ITD and the extent and nature of technological capability investments, and that the framework has to be conducive to industrial development as a whole. This is entirely justified. ITD is an essential and integral part of industrial development, and the factors that affect the latter necessarily affect the former. Long-term investments in capability development and R&D are bound to be exceptionally sensitive to incentives arising from the macroeconomic and competitive environment, which determine the "demand" for ITD.

Given the implicit significance of incentive factors, it is important to understand the kinds of incentives the Bank regards as conducive to ITD. While the precise incentive requirements of ITD are not discussed explicitly in the project documents, it is possible from their analysis and from other Bank writing on industrialization to decipher the Bank's view of the ideal incentive framework for capability development. It is one that meets the following four conditions:

- It provides a liberal trade regime, with considerable exposure over time to international competition in all its forms (import as well as export competition). The case for protecting particular activities to promote ITD or to exploit technological linkages or externalities is generally more than counterbalanced by the risk of government failure in exercising selectivity.

- It provides full access to foreign technology and equipment in all its forms (licensing, service and consultancy contracts, turnkey projects, arm's length purchases, joint ventures, majority-owned foreign investments, and so on). Foreign technology in all forms is seen as a necessary input into domestic technological effort, and the "make or buy" choice on technology is best left to individual enterprises responding to competitive market signals. There is no reason to restrict technology imports or to prefer certain types of technology imports over others.

- It promotes domestic competition, removing all artificial constraints to entry and exit.

- It emphasizes the role of the private sector, on the assumption that private ownership provides a more efficient form of ownership and better incentives for ITD than public ownership.

These criteria are based on the Bank's experience of industrial development in a range of countries pursuing a range of industrial policies. On both theoretical and practical grounds, they have much to recommend them. ITD is strongly driven by international competition. Technology imports are a necessary input into local capability development, and attempts to impose technological "self-reliance" are generally disastrous for healthy ITD. Selectivity does not have a good record, and picking technological winners is especially difficult. Domestic competition is conducive to ITD and to efficiency and growth. Finally, the private sector is generally more efficient and responsive to market signals than the public. The experience of ITD in the sample countries suggests, nevertheless, that *some of these conditions need qualification*. The main qualifications are discussed below.

Trade regime. The presumption that untrammeled competition in world markets provides the most effective stimulus for resource allocation and investments in technological learning is critically dependent on several conditions regarding the efficiency of markets. These conditions are often not met in developing countries, leading to the risk of underinvestment in ITD by enterprises. As discussed in the analytical framework, there may be valid grounds for *infant industry protection* when certain types of market failure are present. Experience shows, however, that the interventions are best located in a *strongly export-oriented regime* that offsets the disincentive effects of infant industry protection while providing the competition and information benefits of participating in world trade. The need for protection, moreover, declines as ITD progresses. With the progress of technological learning, industries have to be exposed to import competition to stimulate further ITD—but the exposure should not be so sudden that the learning process itself is aborted (see below).

Accepting that world competition is a powerful inducement to efficiency and that much of the history of import-substitution in the developing world has been wasteful, it is still the case that ITD in complex industries can require protection, and that deepening of ITD can require longer protection than the mastery of operational capabilities. In the absence of such interventions, the industrial structure may take a very long time to deepen, and comparative advantage may stay confined to relatively easy activities. Within the present sample, India, Mexico, and Spain have many instances of complex industries, unlikely to have been set up under free-trade conditions, that attained technological "maturity" behind protective barriers. The export surge in Mexico in the late 1980s, following massive devaluations and export liberalization, was overwhelmingly led by previous import-substituting industries that had acquired the necessary operational capabilities. Much of Spanish heavy industry was very similar. There are some comparable instances emerging even in relative industrial newcomers like Indonesia. None of these trade regimes were as well planned or rigorously administered as that of Korea, especially in their abilities to offset the disincentive effects of protection. Their effects on ITD were therefore less dramatic. But some of the benefits for capability-building are nevertheless present.

However, the immediate policy issues confronting the Bank and the developing world now are less to do with the promotion of infant industries than with the *restructuring of existing industries* under structural adjustment. Here too the issues of promoting technological learning surface, but in a different guise. For economies with a number of industries that have attained maturity (or near maturity) under protectionist trade regimes, liberalization allows these industries to exploit immediately their existing technological capabilities in world markets. It induces them to upgrade their technologies and to take on related activities, and allows them access to imported equipment and know-how that may have been restricted before.

These benefits of liberalization are very significant. However, there may be a case for phased programs of restructuring and relearning in some industries. Moreover, as the comparative advantages shift and new low-wage exporters enter the international markets, the need for ITD efforts increases not only for the countries to retain their hard-won share of the market but also for them to enter new areas of comparative advantage. It is in this respect that the experience in Japan, Korea, and Taiwan (China) is full of lessons for other developing countries.[3] The Bank acknowledges this case, but is generally averse to programs that have a large discretionary element and so run the risk of government failure. The Bank's approach to trade strategy may thus underestimate some of the critical elements of industrial technology development.

Technology imports. The presumption in Bank documents that technology imports are essential to ITD is justified. Arbitrary interventions in the technology transfer process have often inhibited ITD on grounds of promoting technological self-reliance. In the sample, the case of India illustrates clearly the risks of trying to control all aspects of technology transfer and attain technological self-reliance.

Accepting the critical need for access to foreign technology, however, there is a need to distinguish between technology imports that *complement local ITD and those that substitute for it.* This distinction is stressed in Bank documents on ITD. The projects in Mexico and Spain, for instance, had as their (legitimate) objective the reduction of dependence on foreign sources of high-level technological functions. This was based on the concern that enterprises were investing too little in their own design, development, and innovation. It was noted in particular that affiliates of foreign multinationals tended to spend little on local technology apart from that needed to adapt to local conditions. In other words, foreign technology was tending to substitute for local efforts to deepen ITD rather than to complement it, and was constricting an important source of dynamism and competitiveness.

The Bank's explanation for this differed between the two countries, as did the remedies suggested. In Spain, with its relatively open economy and mature industrial sector, excessive technological dependence was traced mainly to the lack of knowledge and understanding on the part of enterprises of the value of R&D, and secondarily to the weak capital-goods sector and a lack of linkages between enterprises and the S&T infrastructure. The solution proposed was the setting up of a new institution that would catalyze R&D. It would do this by selecting foreign technologies, teaching firms the value of R&D, and involving them in research in-house and in collaboration with research institutes.

In Mexico, with a large industrial sector and very little R&D, the problem was traced to the legacy of import substitution and lack of international competitive pressures, and again secondarily to the weak local capital-goods sector. Here liberalization by itself was assumed to create the necessary demand for ITD, with no further need for interventions in the incentive structure. The experience of Spain was not mentioned. The assumption seemed to be that pressures to achieve operational efficiency in response to liberalization would also lead to pressures to invest in R&D (that is, know-how development would automatically lead to know-why acquisition). It was not considered that free access to technology imports, in a liberalizing environment where there is little habit for undertaking R&D, was more likely to lead to *more rather than less dependence* on foreign design and development (even when firms were upgrading their operational capabilities).

The other projects did not address this issue explicitly. Hungary was a mature industrial power with high levels of innovative expenditure; its problems were essentially systemic. Indonesia was at too early a stage to warrant investments in innovation (though evidently the Indonesian government thought otherwise). India had already invested too much in know-why in a distorted environment. Korea had managed, by a combination of protection, internal resource allocation, and other measures, to develop a research culture among its dominant enterprises. More important to the present analysis, Korea intervened in the technology transfer process to favor arm's length modes that would allow local firms greater autonomy and induce them to invest in their own technological deepening. These interventions differed in effect from the Indian, in that in Korea they were part of a coherent strategy of developing an internationally competitive and diverse industrial structure, and did not confuse the economic objective with other noneconomic aims. It is not clear that the other countries had the administrative capabilities for Korean-style interventions.

This would not matter if technological deepening was *not* an objective of industrial technology policy, that only operational efficiency mattered. However, the ITD projects certainly did not assert this. On the contrary, it was strongly argued that technological deepening was conducive to competitiveness and growth. It was not considered that this objective could require more far-reaching measures to change the entrenched habits of the industrial firms, using trade and industrial strategies to promote ITD, providing strong incentives to indigenous industrial R&D, and even restricting easy access to "ready made" imported technologies.

Domestic competition. There is no doubt that the Bank's emphasis on removing barriers to domestic competition is salutary for ITD in most countries. Most interventions by means of licensing, reservations, ownership restrictions, subsidies, and the like serve mainly to deter and distort technology development. The only exception that may be admitted is based on the *need for large firm size* to bear the costs and risks of technological deepening (and to internalize imperfect markets for capital and skills). Korea used the fostering of giant conglomerates as a deliberate strategy to implement its industrial and technological ambitions, and was able to discipline them by exposure to export competition, internal monitoring, and performance requirements. This may not, however, be an easy strategy to adopt for other countries.[4]

Capabilities and institutions

The Bank's ITD projects exist because there are perceived market failures in the capability and institutional needs of ITD. The sample projects show a fairly good awareness of the main gaps in the factor markets affecting the "supply" side of ITD: skills, finance, infrastructure institutions, linkages between the infrastructure and industry, and access to foreign technology. They also show a due appreciation of the fact that many of these gaps are universal, and most of the project appraisal reports start with the statement that advanced industrial countries also intervene in these markets to support ITD. This is entirely correct. While national approaches differ, all these countries have intervened extensively in the creation of skills, information support systems, infrastructure institutions, technological services for SMEs, finance for exceptionally risky research projects, and sometimes the launching of collaborative R&D across enterprises or between industry and government.[5] There is therefore little disagreement that certain market failures are pervasive in this sphere of industrial activity.

The ITD projects show due appreciation of the differences in the levels of industrial development that affect the nature of the most immediate market failures in each country. However, as noted below, there tends to be a *compartmentalization* of approaches to the different elements of capability development that sometimes prevents the projects from taking an integrated view of the ITD process. This was noted for the Bank's approach to industrialization as a whole in the OED study on this subject.[6] The problem appears in the ITD context in perhaps a less acute form, but it is worth noting, especially in issues of skill development.

Skills. The Indonesia project is the only one in the sample where technical training and educational needs of technology development are addressed directly. The other projects have relatively minor components for training essentially to administer the technology loans. This pattern may reflect one or both of two assumptions: first, the other countries have significantly better skills for ITD than Indonesia, or, second, the skill needs for ITD are being addressed by other Bank projects or by the government concerned.[7]

It is difficult to determine if these assumptions are valid, because no evidence is provided on whether the skill needs of ITD are in fact adequately met. The evidence of the country studies shows large variations in their output of high-level technical skills. According to all the available indicators, Korea leads the field in its enrollments in tertiary level S&T fields and in the employment of scientists and engineers in R&D. Its investments in human-capital formation consistently tended to outrun those in other needs of ITD, though the high rates of industrial growth ensured that any slack created was quickly taken up. By contrast, India and, surprisingly, Hungary come near the bottom in terms of skill creation. It is possible that these countries have a large enough base of specialized research and other skills to "go on with," but it is also possible that many specialties are lacking. More importantly, it is not clear that the majority of industrial enterprises, as opposed to S&T institutions, have the necessary skill base to absorb and implement technological improvements. The project documents do not provide the answer.

Finance. The provision of technology financing was one of the main objectives of Bank ITD projects, based on the presumption that capital-market failures were one of the main constraints to technology development. This was correct, and the particular attention that the projects paid to the needs of SMEs was welcome in that these enterprises face greater financial constraints than large enterprises. The Korea project had venture-capital and other new technology financing instruments as its exclusive focus. The Hungary, India, Mexico, and Spain projects had it as a major focus, along with efforts to remedy failures in information markets. The aim of the finance component differed across countries. The Spain project was to finance the import, development, and diffusion of selected technologies as part of a specific strategy of changing the country's technology culture. The Hungary project was primarily to provide loans for the import of up-to-date equipment and technologies from the West for process control and software. The India project was to finance local innovative efforts via venture capital, while the Korea and Mexico projects were to finance both the absorption of foreign technology and the commercialization of local technologies. These three projects did not attempt to select the technologies or industries where ITD was to be promoted. The general objective of financing ITD was clearly justified in view of the evident failure in capital markets. However, three points need to be made about the design of the projects.

First, in the sample projects, there appears to be altogether too much attention to R&D financing rather than the more mundane needs of training, quality improvement, improved mastery of technology, and so on. These operational improvements were presumably assumed to be met by ordinary sources of finance for working capital. While it is true that most countries in the sample are among the NIEs, and may have long industrial tradition, this lack of attention to other capabilities may have constrained the industrial technology development of SMEs to the extent that these improvements needed more than working-capital financing, and normal banking channels may not have funded slightly longer-term needs without collateral. Thus, these technological upgrading needs may have fallen "between the cracks" of immediate production and research financing. The Korea Technology Development Corporation loans were meant to fill the gap between burgeoning *chaebol* R&D on the one hand and infrastructural R&D on the other. In the other countries the strategic setting was different, and this surge in private sector R&D was lacking. Thus, efforts to meet the needs of private enterprises in technology investments may have been less effective.

Second, the purposes for which technology finance was provided included the development of local technologies as well as the absorption and adaptation of imported technologies. Bank projects did not, correctly, draw a distinction between these. There was nevertheless a stated preference for supporting local development of technologies, that is, for creating a will to carry out R&D, rather than for the less demanding task of adapting imported technologies. However, there was no mechanism conceived whereby this could be achieved. Thus, the technological content of the subprojects financed varied greatly from one country to another. In Korea there appeared to be a fairly high proportion of local innovations, in Mexico rather low. As noted above, the habit to undertake technological efforts by the countries was determined by many other policies than the provision of technology finance, and the Bank's apparent belief that plugging the financing gap would suffice to catalyze local R&D was misplaced.

Third, as disillusionment grew with the experience of poor interventions in most developing countries, the financing component of the ITD projects moved away from targeting specific activities.[8] In Mexico, perhaps in accordance with the government's own perceptions, the tendency has gone further. In its new project on science infrastructure the Bank has withdrawn from industrial technology financing as such, apparently on the grounds that no such targeting is required.

However, as argued, this approach overlooks the legitimate case *for* targeting, and ignores the positive experience of selective interventions in the best performers in the developing world. Despite the Bank's unsuccessful early experience with targeting, there is always a risk that scarce technology resources may be "spread too thin." While there is a strong possibility of government failure in all policies that permit large discretionary powers, *as long as there were differences in learning potential and externalities across activities*, a careful and limited use of targeting may be beneficial. Thus, concentrating resources where such potential and externalities exist might yield more benefits than spreading them over the whole manufacturing sector.

S&T institutions. The strengthening of the *information and technical services network* generally involved two objectives: improving the capabilities of S&T institutions, and establishing closer linkages between them and industry. The strengthening of institutions was a major objective in three of the projects (four if the skill

development for the nonministerial government institutes in Indonesia is included).
In India, the project fed into the government's broader market-oriented reform of the Council for Scientific and Industrial Research institutions, as well as improving the Standards Board. The India project envisaged loans to research institutions in the context of a wider reorientation of the Council network launched by the government. These loans were to be administered and monitored by a private-sector financial intermediary (Industrial Credit and Investment Corporation of India), and would be based on criteria that included interaction with industry. In Mexico, the project envisaged the tying in of investment in research institutes to their partial privatization. It also included a study for a metrology center. In Hungary, the project included strengthening the metrology center and quality control centers, and the selective boosting of infrastructure provision of inputs into R&D.

The needs to improve research institute and industry linkages were mentioned in most projects, though in Hungary and Indonesia they did not appear as immediate objectives. In Indonesia, the need for better linkages was particularly pressing, and the failure to address this is a major weakness of the project. In Spain, too, the project made explicit provision to promote linkages. The Mexico project adopted a different approach. It sought to finance the restructuring of some CONACYT institutes as part of a privatization program. This assumed that a group of private enterprises, for the most part with little research tradition, would have an interest in financing and managing these centers. The output of these centers consisted partly of technological services that were amenable to sale, partly of development work that involved secrecy and so would not easily by entrusted to such centers, partly of the provision of "public goods" on which rewards would be difficult to appropriate. The feasibility of such privatization, and the hope that this would become a substitute for in-house R&D, was evidently not well thought through. The risk that a few large enterprises would dominate the centers for their own benefit was not considered. Thus an apparently imaginative solution turned out to be impractical. In India, there were conditional loans to enterprises to encourage them to sponsor research at the institutions. The scheme seemed promising and appropriate. KTDC, too, sponsored and financed research at institutions, but the government also had other, larger, schemes to bring industry and institutes together on "national projects" in technologies selected for their strategic importance. However, the experience of the KTDC shows that even there it proved very difficult to create strong linkages between private firms (in this case, mainly SMEs) and the research institutions.

Lessons learned and recommendations

Based on the experience from the industrial technology projects in the sample countries the following factors may be cited as those most instrumental in the outcome of the projects.

ITD should form a part of a broader strategy for industrialization; otherwise its impact may be diluted. There is need for an integrated approach in the preparation of ITD projects where incentives, technological capabilities, and institutions are all discussed and addressed simultaneously.

The impact of a technology project on ITD depends on the existence of a clearly defined and articulated technology strategy. The projects in Korea were effective because the Korean government not only had a strong hand in directing the economic and especially the industrial development of Korea, it also formulated a clear strategy for the technological development. This was the case, to a lesser extent, in many of the other countries and where there was need, the Bank insisted on a technology policy study to be carried out.

Since the industrial technology projects usually address issues of the factor market failures on the "supply" side, it should be reiterated that the incentive framework is a crucial determinant of ITD. In addition to a sound macroeconomic setting, liberal trade, industrial, and technology policies play a decisive role in promoting ITD. Where the incentive regime is highly distorted—as in Hungary at the time of the project's inception—even well designed measures on the supply side do not lead to a dynamic process of ITD. ITD projects should, therefore, not be implemented until the economic environment is conducive to their potential success.

Access to foreign technologies is critical to ITD, and the Indian case study illustrates the damage that may result from widespread and severe restrictions on technology imports. However, the mode of technology import may affect the extent and nature of local capability development. A heavy reliance on foreign direct investment can be an extremely effective method of transferring operational know-how of new technologies, and can have numerous beneficial externalities. It may not, however, be the best way to promote technological deepening. In Korea, the preference for arm's length technology imports over direct investment encouraged local enterprises to invest in their R&D capabilities, because it was complemented by a battery of policies encouraging industry to enter complex areas while forcing them to face export competitions.

The deepening of industrial technology capability may also need interventions in trade and technology regimes that promote local research activity. Exposure to international competition and technology flows by itself may not—as witnessed in Mexico and Spain—be sufficient for the promotion of technological effort. The Bank should examine its understanding of what drives the process of technological development and the creation of an R&D culture, paying particular attention to the effects of imported technology inputs versus local technology development.

Technological dynamism requires a heavy involvement on the part of the private sector in technological activities. The role of public institutions in technology should decline over time to provide support for private technological activities. Very few countries have managed this transition. In the case of Korea, this involved, in addition to clear trade, industrial, and science and technology strategies, several financial and fiscal measures to encourage private-sector R&D. Conversely, in Mexico formal technological activity was very low, and nearly all of it was in public institutions. Given the nature of R&D activities, government policy should encourage private R&D through incentives including fiscal and other measures.

Technological effort is necessary for efficient industrialization at all levels. Though the Bank's ITD projects have so far been mainly concentrated on NIEs, they should be started in less industrialized countries. In some developing countries, what may be initially required to promote competitiveness and efficiency are the improvement in skills and an efficient technology infrastructure (for standards, metrology, quality assurance, and so on) before elaborate R&D facilities are created.

Long-term trends in technology affect competitiveness and technological response of each country. Although the Bank cannot specialize in all such technologies, it nevertheless needs to have some idea of the critical areas of generic technologies on which developing countries may need guidance. This would give more meaning to its industrial technology development lending activities.

There is need for the dissemination of ITD literature within the Bank and a serious discussion of the subject. ITD projects are currently carried out by a few individuals in the Bank who understand the imperatives of technology development but often find it difficult to communicate their concerns to others. This is all the more important because of the Bank's preoccupation with the supply response and competitiveness that is expected from trade and industrial policy reform and industrial restructuring.

Project implications

In financing R&D by firms, the Bank should look for intermediaries that understand R&D, have technical expertise, are knowledgeable about various industries, and are committed and willing to take risks. The ownership of the project should, therefore, be vested in only dynamic organizations that are willing to lead, facilitate, and monitor progress in the interest of efficiency. Normal financial intermediaries like commercial banks are generally not equipped to deal with the needs of such financing, and it is desirable to entrust such activities to specialized financial institutions.

Successful financing of technological innovation in industry depends on the institutional make-up of the financial intermediary. Though the government's presence may be necessary to get started, the intermediary should have strong private-sector participation and support as well as complete autonomy so that bureaucratic interventions are avoided. The Indian and Korean experiences illustrate the advantages of privately managed institutions that are responsive to market needs and have intimate relationships with industry. Conversely, in Mexico the first-tier commercial banks had very little inputs in the technology loans.

Successful technology and venture-capital financing depends, to a very large extent, on the experience and quality of the staff of the institutions. Not only should the institution attract and retain qualified staff, it should continue to improve their effectiveness through a variety of training programs.

Venture-capital and risk-sharing operations should be approached with great care because the skills required to manage them are not always readily available and take time to develop. In the Indian project, the projectio ns made on the uptake of such financing was overoptimistic. Risk-sharing activities also require the availability of financial resources that permit prudent risk-taking. In setting up the financing of the intermediaries, there is need for reasonable certainty as to the sources of finance, the commitments by the government in terms of assistance, and a well-designed devolution program.

In all the countries in the present study, R&D institutions set up to deal with industrial technologies have found it difficult to link up with manufacturing enterprises. The privatization of public-research institutes faces various difficulties, as illustrated by the experience in Mexico where enterprises were reluctant to take on the ownership and management of such institutes. Since large firms normally have their own resources for R&D, priority should be given to financing R&D for SMEs. Financial incentives to the private sector might help create linkages between SME and R&D institutes.

While it is important to have the private sector represented in the policymaking bodies of public R&D institutes, it is highly unlikely that the private R&D institutions can be put in place through the collective participation of private-sector firms without strong government support and financial assistance. The services of the private-sector private institutions could be brought in to facilitate the linkage between industry and R&D institutes.

The best approach towards strengthening research linkages seems to be one where it is clearly recognized: (a) that only those research institutes with the "service to industry" culture can be instrumental in strengthening the linkage; and (b) that firms, especially SMEs, face *serious information and credibility gaps* in subcontracting research to institutes. This is partly a problem of their inability to define clearly their own technological needs. It is partly due to a lack of knowledge on their part of the capabilities of the institutes and a lack of trust on industrial secrecy. These gaps can be filled best by subsidizing, at least at the start, the process of linkage creation, while securing some financial commitment on the part of the enterprises. Many of the ITD projects did recognize the need for this subsidization, and it took the form of conditional loans, preferential interest rates, targeting selected activities, and so on. This approach was correct, though a systematic assessment of the form of support that works best is still lacking.

Notes

1. For instance, the Tamil Nadu Newsprint Project in India (Loan 2050-IN) used a chemi-mechanical pulping process developed at TNPL for the production of newsprint from bagasse. A subcomponent of the Fertilizer Rehabilitation and Energy Saving Project in China (Loan 2541-CHA) consisted of strengthening the newly established China Fertilizer Development Center and fertilizer design and research institutes for improved R&D and engineering capabilities in the fertilizer industry. In Jordan, the Second Arab Potash Project (Loan 2786-JO) helped the pilot plant trials for the development of a cold crystallization process that was eventually used in the third expansion of the project.

2. See W. M. Cohen and D. A. Levinthal, "Innovation and Learning: The Two Faces of R&D," *Economic Journal*, 99, 1989, pp. 569–96.

3. Korea was exceptional in the diversity of measures it used. It gave grants and subsidized credit for R&D in areas regarded as strategically important, both for in-house activity by firms and for collaborative work with the research institutes. Its tax incentives for R&D were extremely generous and given years in advance. Innovators received preferences in procurement, and were given awards and citations. It gave privileged access to importers of research-related equipment, and invested in setting up "science towns" that brought together universities, research institutes, and industry. It guided and promoted R&D in activities of strategic importance. In addition to the primary urge for technological deepening that came from the trade and technology import regimes, this pervasive set of measures to encourage and catalyze private R&D clearly helped to promote technology development in Korea. Grants were also used in other countries to stimulate R&D between the industry and research institutions.

4. The situation in Taiwan (China) is totally different with the preponderance of small- and medium-scale industries.

5. For a historical review of government policies on technology in the developed countries, see D. C. Mowery and N. Rosenberg, *Technology and the Pursuit of Economic Growth*, Cambridge: Cambridge University Press, 1989. On the current practice in Japan, the US, and some European countries see the Office of Technology Assessment of the US Congress, *Making Things Better*, Washington, DC, 1990.

6. To quote, "The functional division of work does not permit an easy integration of educational, industrial, institutional and macroeconomic disciplines. These divisions themselves reflect the academic and other distinctions that have grown over time between these subjects. They are not difficult to break down, but it would require deliberate effort of building intellectual as well as bureaucratic bridges." OED, *World Bank Support for Industrialization in Korea, India, and Indonesia*, 1992, pp. 53–54.

7. The Bank had a number of technical training and education projects in many of the sample countries. But in most countries (except Indonesia and Korea) the question of education and training in science and technology is not explicitly addressed. In India and Mexico training of technicians was the major objective and, even in Spain, the Bank approved two education loans in the early 1970s.

8. The Hungary project was something of an exception, but the selectivity recommended may have been justified with reference to the lack of market institutions there.

Annex

Technology and growth: definitions

A virtuous circle connects technological progress and economic growth. Ever since the path-breaking work by Robert Solow in 1957, technological progress has been empirically identified as one of the most important factors in determining economic growth. On the other side of the circle, economic growth feeds advances in technology by making technical advances economically profitable.[1] Growth raises the demand for technology and makes investment in technological progress profitable. Growth also contributes to technological progress through increasing the stock of knowledge that arises from learning by doing—that is, from obtaining more experience with production. Thus growth and technological progress reinforce each other through this virtuous circle.

In this annex we address one half of this virtuous circle: how does technological progress contribute to growth and development? The first step in answering this question is to define technology carefully. Technology may best be thought of as the available knowledge, the stock of ideas, or the 'set of recipes' available to combine and transform material factors of production, such as land, labor, and capital, into output. This recipe set, or existing knowledge, is embedded in the available machinery and equipment and in the training of the work force. The available technology for production in any economy, in practice, however, ranges between those that are efficient and represent 'best practices' and those that are inefficient, requiring greater quantities of inputs than in the best practice cases to produce the same levels of output.

Following this definition, technological progress can then be seen as the increase in the stock of knowledge or ideas, or a change in the recipe, that enables an economy to produce on average a greater quantity of output without increasing the amount of inputs. This technological progress and its effects upon growth can take place in two ways: (a) an improvement in the 'best practice' or efficient technology (this is termed as invention or innovation), and (b) an increase in production that uses best practice technology, for example, the average technology in use improves and comes closer to the best practice frontier. This is known as the process of imitation, or alternatively as the process of diffusion of technology. In either case the immediate effect upon growth is quantitatively the same: it lowers the amount of inputs necessary to produce the same level of output. It thus releases resources to produce more output and thus causes economic growth.[2]

While the immediate effects of both processes of technical change on growth are the same, it is the first process of technological progress that will be decisive in sustaining growth of output in the long run. The second process, the improvement of 'average' technology, is necessarily limited by the frontier of best practice; at some point the scope for output growth through imitation will be exhausted in the absence of new innovations and inventions. Lastly, as the potential for the indefinite accumulation of material factors of production, such as capital and minerals, may be necessarily limited, technological improvement provides the only route through which economic growth can be sustained.

The rest of this annex is organized in the following way: in the next section we present empirical evidence to show the influence of technical progress on economic growth. We then turn to a discussion of some of the ways that technical progress affects growth.

Empirical evidence: productivity and costs

The principal manifestation of technological progress in economic growth follows from the nature of technological progress: Technology is like a factor of production, but hidden behind capital and labor. Consequently, any 'increase' in technology manifests itself as an increase in multifactor productivity; that is, it leads to a rise in output beyond what can be accounted for by the rise in capital and labor inputs. The effect of this boosts the growth rate. Equivalently, technological progress leads to a fall in unit costs of production. As less inputs are required to produce one unit of production this releases factors for use in production elsewhere. Thus economic costs, or opportunity costs, fall. In this section we present some evidence on both of these indices.

Productivity

In 1957 the pioneering work by Robert Solow revealed the striking result that less than half of the growth rate of output in the US economy, between 1909 and 1949, could be explained by an increase in the use of material inputs like labor and capital. The remainder of the growth rate remained unexplained, a residual.[3] It was suggested that this residual was explained by increased technical efficiency in the use of factors of production and not to the accumulation of these factors. This finding indicated that technological progress probably played a highly significant role in determining long-run growth of the economy. Indeed, Solow's work, later generally confirmed by similar exercises for other Organization for Economic Cooperation and Development (OECD) countries, suggested that as a factor the contribution of growth in productivity to overall growth in production was more important than contribution from the accumulation of capital. This result is also confirmed by looking at growth in several OECD countries. Figure 1 compares the contribution of total factor productivity (TFP) catch-up and the unexplained productivity residual against the contribution made by capital deepening to relative growth rates of several OECD countries.[4] Thus ever since Solow revealed these results economists have been sharply aware of the potential importance of technological progress as a determinant of growth.

Later studies of the sources of long-run economic growth have further refined these early studies by carefully decomposing the residual, g_{TFP} into several possible components: (a) the gains from increasing returns to scale; (b) the gains from intersectoral reallocation of labor; (c) the gains from increases in allocative efficiency; and (d) the pure gain from the contribution of technological progress. Also, considerable effort has gone into accounting for changes in the quality of labor and capital inputs to isolate the measure of technical change contained in the residual.[5] Nevertheless, even after all these refinements the importance of growth of technological progress has continued to be emphasized in these studies.

Studies on the growth of total factor productivity and its contribution to economic growth and development are generally extensively available for developed OECD countries. Recently there have also been some studies that estimated total factor productivity growth and their contribution to developing countries.[6] However, work on the decomposition of total factor productivity into its various parts is generally at the preliminary stage. As such there is less direct evidence available on the role or contribution of technological progress to recent growth in developing countries. However, observations on total factor productivity across countries reveal some interesting patterns. These patterns offer some useful insights into the nature of technical progress and their potential contribution to economic growth in the less developed economies. We summarize these patterns here:

(1) As a source of growth, the contribution of raising productivity through technology is more important than many other factors. In the case of the US in the post-war years, for instance, the contribution of pure technological progress to annual growth rates was three times the contribution of gains in allocative efficiency.[7] The contribution of technical progress in middle-income developing countries is also quite significant. After accounting for intersectoral reallocation of labor in lower-middle and upper-middle-income, total productivity growth varied around 1 percent on average for the lower-middle-income and the upper-middle-income developing countries (see Table 1). Thus as a source of growth in developing economies in the long run, technical progress is potentially considerably more important than possible gains from removing distortions in resource allocation. While technical progress sustains growth in productivity annually, the gains for removing resource misallocation is by nature of a one-shot kind.

(2) The contribution of technological progress through increasing productivity increases with

TABLE 1

Country income group	*Aggregate total factor productivity growth*	*TFP growth net of labor reallocation effects*
Low income	0.3	-0.38
Lower middle	1.3	0.75
Upper middle	1.7	1.15
High	1.8	1.80

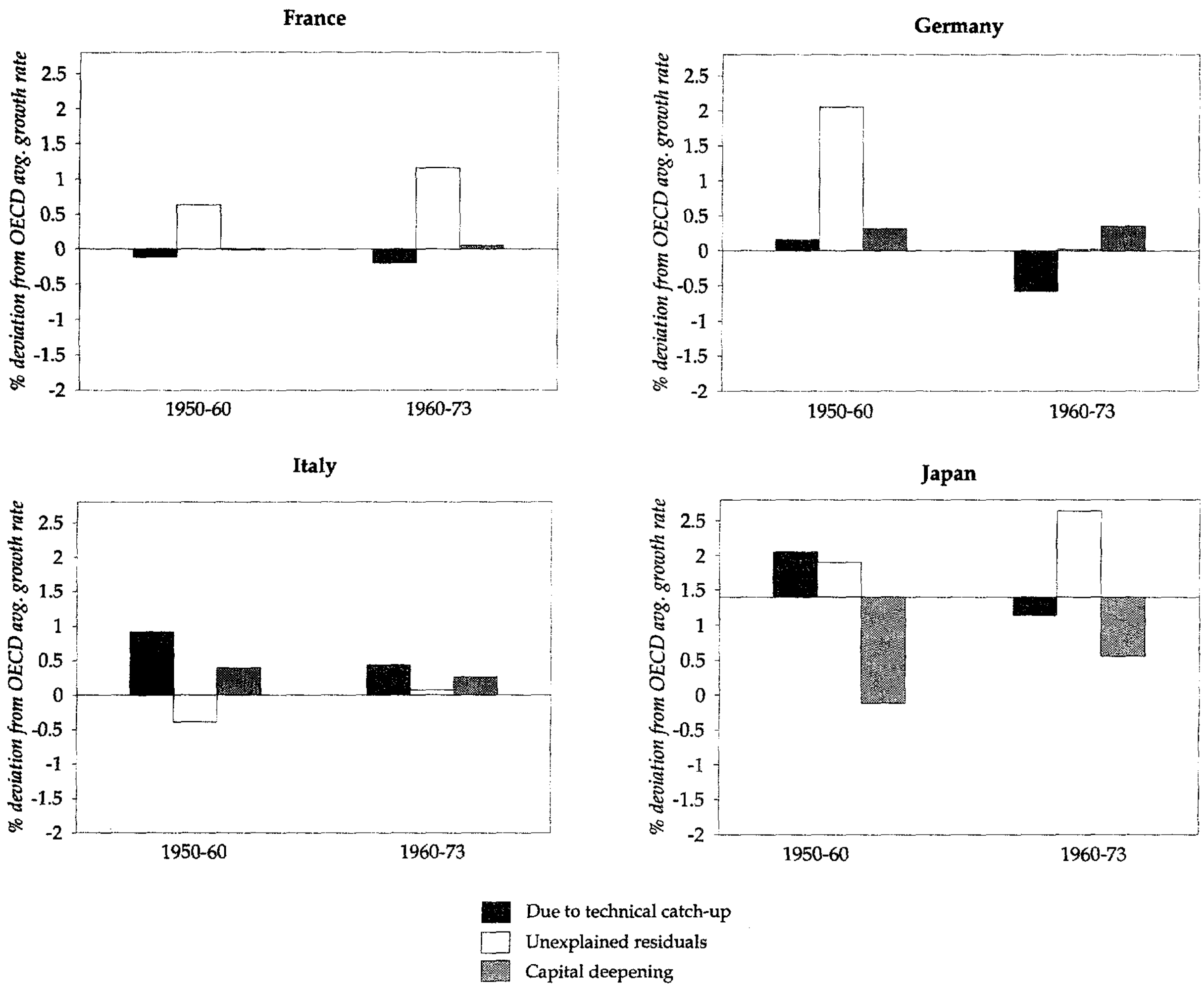
Source: World Bank.

the stage of development. In general empirical estimates show that the contribution of total factor productivity to growth is much less significant in the poorer developing countries than in upper-middle-income countries and in rich developed countries (Table 1, Column 3). Thus in the early stages of growth it is the accumulation of factors of production rather than growth of productivity that accounts for growth in poorer countries.

For the poor or lower-middle-income group of countries, the contribution of technical progress per se, after isolating the impact of sectoral reallocation of labor, is much less. In fact, for the very poorest group of countries, the technical residual is actually negative, showing a regression in technical efficiency in these countries. This suggests that technical progress and economic welfare, as measured by per capita income, are significantly connected at both ends of the scale: in upper-middle-income and rich countries the contribution of TFP growth and technological progress is high, while in poorer countries multifactor productivity seems to be actually falling.

(3) Most significantly, these patterns of productivity across countries reveal that the transfer of technology across borders through imitation of international best practices is not automatic across all countries. The famous Gerschenkron hypothesis states that backward countries have an advantage in that they have to incur less

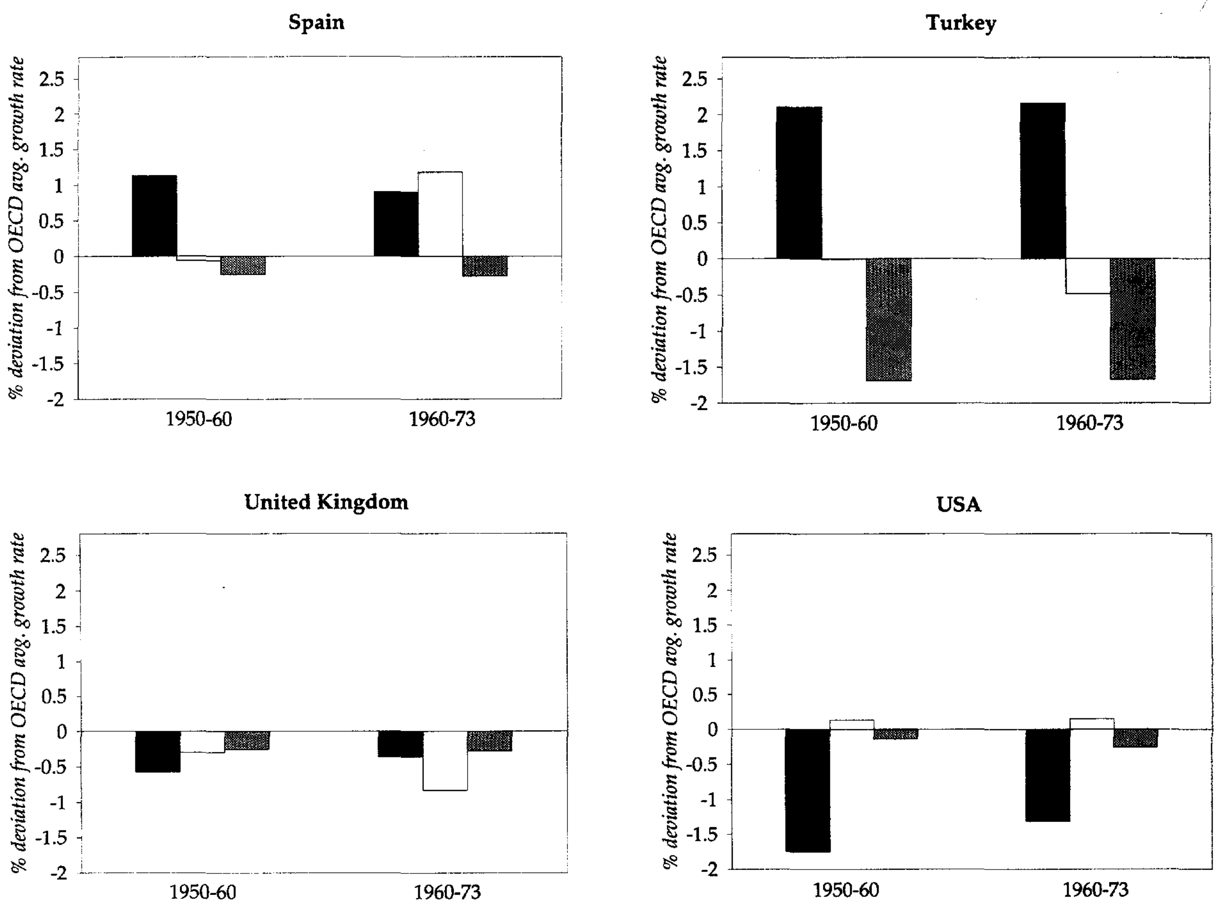
FIGURE 1: CONTRIBUTIONS TO RELATIVE GROWTH



costs to develop the 'best practice' technology, and can instead imitate what is available in the advanced countries. The data on productivity patterns lend only qualified support to the advantages of backwardness suggested by this hypothesis. Convergence of productivity and incomes, suggesting successful imitation of technology, holds only for advanced OECD countries and upper-middle-income countries.[8]

As Table 1 above shows, upper-middle-income countries have caught up with developed OECD countries in terms of growth of total factor productivity. More specifically recent studies on the causes of growth of high performing Asian economies reveal two interesting things. One, they show that the growth of total factor productivity has been exceptionally high for high-growth economies such as Hong Kong, South Korea, and Taiwan, suggesting the important contribution that technical progress makes in the growth of these economies. Two, there is some evidence that some other high-performing Asian economies, like Indonesia,

FIGURE 1 *(continued)*



Source: Computed from S. Dowrick and Duc-Tho Nguyen, "OECD Comparative Economic Growth 1950-85: Catch-Up and Convergence," *American Economic Review*, 79, No. 5, 1989, pp. 1010-1029.

Malaysia, and Thailand, where growth has been driven mainly by investment in the past few decades, may have entered a phase where increase in technical efficiency is a more important contributor to growth. This suggests that the contribution of technological progress to growth increases with the level of development. The increase in the knowledge pool, the training of labor, and the development of overall technological capability of the country (all of which accompany development) enhances the ability of the country to use technology for production.

(4) Technological growth, economic growth, and investment in human capital are closely linked. Cross-country studies on the determinants of per capita income growth show that *the extent to which poor countries can catch up with rich countries—that is, imitate best practice successfully—depends on the quality of its labor force, its endowment of human capital.*[9] This suggests that the contribution of improvements in technical efficiency to economic growth depends on the country's capacity to absorb technological progress (that is, its technological

capabilities). We raise this theme again later, as a major issue.

Costs

As discussed in detail earlier, technical progress is a 'hidden' factor and contributes to economic growth and development by raising total productivity of all the factors in use. This also means that technical progress contributes to growth by decreasing the costs of production. To the extent such costs represent opportunity costs for the factors in use, the fall in costs reflects the additional goods and services that can now be produced. This then contributes to output growth.

There are some spectacular examples from economic history on the dramatic reduction in costs of some fundamental goods caused by technological progress. The use of the Bessemer process reduced the cost of making steel in twenty years from $100 per ton in 1870 to $12 in 1890; the cost of production of blue dye alizarin on a large scale brought production costs from 200 marks per kilogram in the mid-1870s to nine marks in 1886; the introduction of the Hall process in making aluminum reduced prices from 87.5 francs per kilogram in 1888 to 3.75 francs in 1895. Advances in metallurgy, the substitution of steel for cast iron, improvements in machining, and progress in mechanical engineering underlay these spectacular cost reductions and made possible the cheap and mass production of agricultural machinery, sewing machines, typewriters, cash registers, bicycles, and automobiles.[10]

In more recent times there are also equally dramatic examples that can be drawn from advances in information technology whose impact on economic growth seems analogous to that of steam engines and electricity. Advances in modern information technology appear to have conformed with Moore's Law, which claims that the number of components that can be contained in a single microchip will double every year. This law has now held for over 25 years.[11] Consequently, the quality-adjusted prices of electronic devices have also declined at an unimaginable rate. The price per kilobit of dynamic random access memory[12] has declined from more than four dollars in the early 1970s to less than one cent lately; that is, a kilobit of memory was 5,000 times more expensive 15 years ago than today.

Linkages between technological progress and growth

The interaction between growth and technology and between allocative efficiency and technological progress is one of the least understood areas in modern economics. Economic historians have generally stressed the profound importance of technological progress as a factor behind economic growth. In stressing this, historians have emphasized detailed descriptions of the process through which technology and growth interact with each other.[13] Schumpeter, for instance, defined some aspects of development almost synonymously with technological progress: his definition included (a) the introduction of a new good, and (b) the introduction of a new method of production.[14] This definition thus clearly highlighted the central role played by innovation and technology in economic development.

In contrast, neoclassiscal economic theory has paid relatively little attention to the detailed processes through which technology and growth influence each other. In fact, the theory has consigned technology[15] and its role within the black box of a single parameter in the production function. This does not mean that neoclassical theory did not assign any importance to technical progress in economic growth. On the contrary, according to the neoclassical theory technological progress was the chief instrument through which long-run growth rates of the economy could be affected. However, the nature of the technological progress remained entirely exogenous in the model. As such, there was little insight into the disequilibrium and dynamic processes that accompany the development and diffusion of technology.

The more recent endogenous growth theory has provided much greater insights into this question, to some extent by formalizing ideas developed by earlier economists. This line of thinking identifies knowledge, and its public good characteristics, as the catalyst behind long-run economic growth and the high rates of productivity growth that have been maintained in the developed countries. Knowledge and technology are embodied in human capital, and in the range and quality of inputs generally. Technology can also be disembodied in blueprints and books for instance. However, even in the case of 'disembodied' innovation, the rate of innovation is significantly influenced by the economy's endowment of human capital.[16] We turn next to a discussion of some of the themes that link technology and growth.

We list these themes as (a) the development of new inputs and processes; (b) increasing investment in new machinery and equipment; (c) experience and learning by doing; (d) externalities and agglomeration; and (e) the development of human capital and capabilities. Note that these mechanisms are not isolated and distinct from each other. They are treated separately in the ensuing discussion only for the sake of clarity.

Development of new inputs and processes

The development of new inputs and processes is one of the major channels through which technological progress affects productivity and growth. Both theory and evidence suggest that long-run growth and increases in productivity are affected not only by the quantity of inputs used in production, but also by the *greater range and types of inputs* used in production.[17] With the same stock of resources the greater is the range of differentiated inputs available, more specialization and the use of 'finer' production processes become possible. This raises productivity and growth.

The examples of the dramatic reductions in costs that were given earlier also serve as examples of the importance of developing new inputs for technological progress. All those examples—the Bessemer process in steel, blue dye alizarin, the Hall process in making aluminum, and the development of the microchip—share a crucial common characteristic that illustrates the importance of new inputs. These products are, or were in their time, key inputs in a very broad spectrum of economic activities. Thus there is a close association between advances in a few such key technologies and with episodes of major strides in economic growth. The development of the steam engine, electricity, and the modern steel-making processes are commonly regarded as the impetus behind what is termed as the First and the Second Industrial Revolutions.

More recently, inventions such as semiconductors in the industrialized world and breakthroughs in agricultural technology, such as the hybrid corn and the high-yielding rice seed varieties, have revolutionized productivity in industrialized countries and developing countries. The widespread impact of some of these technological breakthroughs has led some to suggest that "whole eras of technical progress and economic growth appear to be driven by a few key technologies"[18] that have multiple purposes—that is, they are used in a broad spectrum of productive activities. The development of such 'general purpose technologies' thus provides some sharp instances of the contribution of technological advancement to economic growth.

Investment in machinery and equipment

Investment in machinery and equipment plays the central role in the contribution of technological progress to economic growth. *It is investment that connects technology with the other key of economic growth: the role of incentives.* Technological progress can benefit growth and development only when there are incentives to invest in such progress. There are stark examples in support of this notion from economic history. When incentives to invest have been absent, the impact of technology on growth has been minimal, even when the technology has been highly advanced in the context of its time.[19] Thus the mere existence of advanced technology, per se, can contribute little to growth.

Technical progress contributes to economic growth through investment in machinery in at least two ways. One, new machinery and equipment embody technological progress and hence raise productivity of capital and labor. Two, advances in technology provide opportunities for profitable investment—provided of course that investment is at all attractive in the first place. A good part of technological progress comes embodied in physical machinery. Advances in knowledge obtained through research and development (R&D) or through experience in production—learning by doing—are incorporated in the design and specifications of new machinery and equipment. Consequently, investment and use of new machinery and equipment have been found to be strongly and causally associated with high rates of productivity growth. This association has been true historically over the past century for a group of six industrial countries for which data were available.[20] It has also been found to be true for a broader set of countries, including several developing economies, since World War II.[21]

Foreign direct investment in equipment and machinery in a country is another path through which technology affects growth. Foreign investment in less developed countries is generally associated with use of equipment and machinery that embody the current 'best practices'. Foreign investors have the required knowledge to make an informed choice of technology in addition to providing the resources to acquire this technology. Thus foreign direct investment becomes an important conduit of efficient 'imitation'; this links technological advancement in industrialized countries (shifts in 'best practices') to increases in productivity and growth in developing economies.

On the other side, technological progress and innovation cause growth by increasing the incentives to invest. The use of new technology by firms increases their market power. The introduction of a new product or of more efficient techniques of production that cut down costs are not immediately or automatically replicable by other firms. Consequently, the scope and opportunity for earning monopoly profits are created for a while. Investment is encouraged by this opportunity of earning monopoly rents. This in turn spurs growth and development in the economy.

Learning by doing

Learning by doing—that is, the gains achieved from greater experience in the workplace—is another important channel through which technology contributes to growth. Technological progress increases the scope for such gains. Over the longer haul, in fact, the gains from technological progress are manifested in economic growth mainly through this channel, rather than through the sudden bursts of invention and innovations developed from formal research and development. Historical evidence suggests that even until about 1875, nearly a hundred years since the beginning of the industrial revolution, the technology used in the West was mostly developed in the workplace by artisans and engineers, who were not scientists by training. A little further back in time, industrial technology in around 1800, including technology of the industrial revolution, was principally derived from learning by doing. Thus technology in shipbuilding, engineering, construction, architecture, mining, smelting, and weaving was based on rules of thumb and craft tradition derived from long experience.[22]

Even later, when formal research and development became a significant part of technology's contribution to growth, the gains derived through learning by doing continued to be important. One of the most significant advances in production efficiency in recent years in the OECD countries is the 'just-in-time' inventory system, which minimizes expensive inventory costs. This system was developed on the factory floor, resulting from experience and trial and error.[23] The new emphasis that is now given to the Japanese concept of Quality Control Circle is also a recognition of the value of learning by doing.

In general, the productivity gains from research and development that lead to blueprints of new products, new inputs, or new processes are not realized at once. Rather it is the experience of implementing the blueprints, of producing new products, and of working with new inputs and processes that leads to the major increases in productivity. However, new inventions and innovations are still vital to the productivity gained through learning by doing. It is the development of new technology that sustains gains from learning by doing. Without the development of new techniques and processes, the scope for productivity gains from learning would be exhausted. Thus this is another way through which technological progress, learning by doing, productivity, and economic growth are related.

Externalities, agglomeration externalities, and increasing returns

Recent developments in economic theory identify externalities, the gains from agglomeration, and increasing returns to scale as principal mechanisms that lead to sustained high-growth rates in the long run. One of the distinguishing aspects of technology is that it possesses some features of public goods. This nature of technology makes technological progress a central element in the various mechanisms of growth suggested by endogenous growth theory.

Technology, or the stock of knowledge in the economy, is a nonrival good and a partially nonexcludable good.[24] First, nonrivalry means that the use of existing technology by any economic agent does not deny its use to other economic agents. For example, like a street light, technology can be used by all who choose to use it. Second, partial nonexcludability means that it is difficult for the party that has invested in acquiring new technology to completely, and for a long time, exclude other parties from using that technology. By nature, technological gains spill over from the original inventor or imitator to other users of that technology.

Thus while the costs of acquiring technology are of a one-time nature, the gains from it keep accruing continually. Therefore, the gains from investing in technology—through direct R&D, learning to work with new equipment, or investing in formal education—can, in varying degrees, be shared by all. This leads to increasing returns in production: output rises at a greater proportion than inputs. Recent empirical work for the OECD economies has shown, for instance, that increasing returns caused by externalities are indeed highly significant at the aggregate level, that is, for the entire economy. When all industries increased their output, the elasticity of output increase with respect to input increase was 1.3 for four European countries and 1.33 for the US.[25]

The benefits of technological spillovers are also reinforced by agglomeration externalities, or the advantages of size. The contribution of technological progress to economic growth, by this viewpoint, is enhanced as technological progress takes place; that is, the contribution of technological progress is a self-reinforcing mechanism. As technological development proceeds, its benefits are spilled pervasively through externalities. More workers get experience with working with new machines and the human capital stock and the knowledge base grows. This process then endogenously reduces the costs for future technological progress. Consequently technological progress receives further impetus. A good indication in support of this comes from location theory and the behavior of foreign investment in particular. Nonagricultural economic activity (manufacturing, for instance) is not spread evenly geographically, but is concentrated in "cores."

The behavior of foreign direct investment illustrates this. The bulk of foreign direct investment goes to these cores, which exist mostly in developed countries, and not to developing economies where labor is cheap. Because technology is more advanced in these countries, important specialized services and critical technical knowledge are more cheaply available. Consequently, returns to new investment are higher there. Closing the cycle, more investment in the core results in yet further development of technology and the pool of knowledge and services available in the core. Growth is further stimulated, and the economic gap between technologically developed and underdeveloped economies increases.[26]

Technological capabilities

The contribution of technology to economic progress in any country is mediated through the country's technological capability: its stock of human, physical, and institutional capital. The more developed and efficient the country's technological capability, the more effective is the contribution of technology to growth. Two important issues are implicitly raised by this notion. One, the mere existence of knowledge and 'best practice' in advanced industrialized countries is not sufficient to ensure that it will be adopted in developing countries. Technology has to be understood in order to make effective use of it. This is the tacitness property of technology.[27] This property then implies that even imitation, the ability to use ideas instead of producing them, is not automatic and costless. Hence, the greater the level of development and investment in technological capabilities, the greater is the contribution of technology to growth.

Two, mere imitation of what is best practice in the advanced industrialized countries may not be 'best practice' in developing economies. This is the result of another characteristic of technology: circumstantial sensitivity. This means that "technology that has been developed for use in one locale is seldom equally well suited to others."[28] In consequence, effective imitation will require the capability to adapt technology developed elsewhere. In fact, in countries like Japan, the key to rapid and systematic growth of technological capabilities and productivity lies in their ability to use 'adapted technology'—the ability to choose advanced technology and adapt it to their own resource availability and skill endowment through a process of reverse engineering.[29]

The importance of externalities and the advantages of agglomeration, as discussed above, the lack of convergence in productivity between less developed countries and industrialized OECD countries, and the importance of using adapted technology suggest that the technological capabilities of a country to use technology for growth have to be systematically developed. This technological capability to efficiently imitate (or adapt) international best practices depends principally on several broad factors: (1) the facilities available in the country for the diffusion of knowledge; (2) the ease with which changes in the composition of output, occupation of labor force, and other structural parameters can take place; (3) the growth of capital investment; (4) endowments of human capital: the existence of a skilled and trained labor force and educational and scientific establishments.[30]

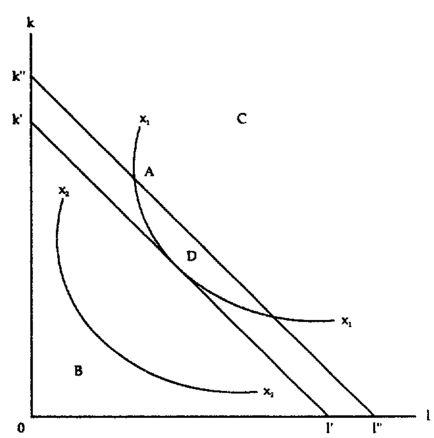
These conditions suggest that in the final analysis there is little qualitative difference between the two different ways that technological progress takes place: (a) through innovation and invention, or producing ideas, and (b) through imitation, or using ideas. Both of these ways through which technological progress contributes to growth lie in one continuing spectrum. Effective imitation requires the ability and the effort to evaluate and choose technology fitting the specific circumstances of developing economies; effort is needed "to acquire and operate processes and produce products; to manage changes in products, processes, procedures, and organizational arrangements; and to create new technology. This effort takes the form of investment in technological capability, which is the ability to make effective use of technological knowledge."[31] Thus this process is not too different from the process of original innovation itself. And finally, the ability to undertake original research and create new inventions and innovation cannot be truly developed in a developing country without mastering the process of imitation, or using ideas.

There is a substantial issue involved here. On one side, contrary to what is sometimes suggested, the gains from 'catch-up' and imitation are not automatic and costless. Developing countries need to invest in technological capabilities to ensure that they can use technology effectively. Only then can technological progress support a sustained rise in productivity and growth. On the other side, it is also true that in the long run the full realization of technological potential can only come from learning to produce ideas, from being able to take part in developing 'best-practice' technology. The investment in technological capability that is necessary for effective imitation becomes particularly invaluable by this light.

Notes

1. We owe Allyn Young's, "Increasing Returns and Economic Progress," *Economic Journal*, 1928, the credit for identifying this cycle.

2. It is important to distinguish between improvement in allocative efficiency and improvements in technical efficiency. While both lead to higher economic growth, we are interested in the latter concept here. We use a simple diagram to clarify what we mean by available technology, the two forms of technological progress, and the difference between allocative gains and technical gains. A more elaborate discussion, where technology and techniques are differentiated, is available in Howard Pack, *Productivity, Technology and Industrial Development: A Case Study in Textiles*, Washington, DC: World Bank, OUP, 1987, p. 8.



In the diagram above the k (vertical) axis measures capital inputs needed to produce one unit of output while l measures labor input needed to produce one unit of output. The least amount of inputs, k and l, that can be used in different combinations to produce one unit of output, x, is given by the curve x_1x_1. The points in this curve represents best practice, the state of technology in producing x. There is no combination of k and l more efficient than the points in x_1x_1. In other words there can be no points to the left and below x_1x_1 (like point B) that is feasible. However, points to the right and above of x_1x_1 (like C) are feasible. It is always possible to produce the same one unit of x with more of k and l. But clearly these are inefficient points.

Now technical progress consists of two components: (1) the process of imitating best practices, moving from points like C to A; and (2) original inventions and innovations that enhance best practice. This removes the curve x_1x_1 to the left and below to x_2x_2, for instance. The effect of either is to raise productivity and reduce costs.

How does allocative efficiency fit here? Allocative efficiency involves the choice between points like A and D—where both represent best practices. Given the fixed prices of k and l, the slope of the straight line k/l/ gives the relative price of k and l. This line (and other lines with the same slope) then can be used to measure the cost of production of x in terms of labor and capital. Assume that the economy produces x using technique D. Then in terms of labor only, l/ is the cost to produce x; in terms of only capital, k/ measures the cost of production. Now given this line, D is more efficient in allocative and economic terms than A (or in fact than any other point in x_1x_1). With these prices a move from A to D leads to allocative gains because it reduces costs from l" to l' in terms of labor. In ending we note that our discussion in this paper focuses on technical efficiency and not allocative efficiency. We are therefore concerned with the movement from C to A or the downward movement of the x_1x_1 curve to x_2x_2.

3. Robert Solow, "Technical Change and the Aggregate Production Function, "*Review of Economics and Statistics*, 39, August 1957, 312-320. This refers to the famous 'Solow Residual'. This can be identified as the following:

$$g_{TFP} + e_k g_k + e_l g_l$$

Solow's results in percent: 2.9 = 1.49 + 0.32 + 1.09

g_{TFP} is the residual and where gy is the growth rate of gross domestic product.

e_k and e_l are the elasticity of GDP with respect to capital and labor respectively. If it is assumed that there are constant returns to scale, then e_k and e_l become equal to the share of income of capital and labor in national income respectively.

g_k and g_l are the growth rates of capital and labor stocks respectively.

Like many other quantitative measures, the interpretation of the residual g_{TFP} as corresponding to technical progress is subject to considerable controversy. Also g_{TFP} includes other components aside from technical progress. Nevertheless g_{TFP} remains the most broadly available and used measure of such. See Zvi Griliches (1991).

4. Relative growth rates refer to deviations from average OECD growth rates.

5. See E. Denison, *Accounting for United States Economic Growth, 1929-1969*, Washington, DC: The Brookings Institution, 1974, and *Trends in American Economic Growth, 1929-1982*, Washington, DC: The Brookings Institution, 1985. See also D. Jorgenson and Z. Griliches, "The Explanation of Productivity Change, "*Review of Economic Studies*, July 1967, pp. 249-283.

6. World Bank, *World Development Report, 1991* estimates of total factor productivity growth in developing countries.

7. See E. Denison, *Trends in American Economic Growth, 1929-1982*, Washington, DC: The Brookings Institution, 1985, Table 8-1.

8. See W. J. Baumol, "Productivity Growth, Convergence and Welfare: What the Long-Run Data Show, "*American Economic Review*, 76, No. 5, 1986, pp. 1073-1085; and S. Dowrick, "Technological Catch Up and Diverging Incomes: Patterns of Economic Growth 1960-88, *The Economic Journal*, 102, 1992, pp. 600-610.

9. See R. Barro, "Economic Growth in a Cross Section of Countries, "*Quarterly Journal of Economics*, 1992.

10. Nathan Rosenberg and L. E. Birdzell, Jr., *How the West Grew Rich*, Basic Books, 1986, p. 213.

11. T. F. Bresnahan and M. Trajtenberg, "General Purpose Technologies: 'Engines of Growth?'," National Bureau of Economic Research, Working Paper No. 4148, August 1992, p. 9.

12. More familiarly, the RAM of a computer.

13. See, for instance, N. Rosenberg, *Inside The Black Box: Technology and Economics*, Cambridge: Cambridge University Press, 1982.

14. The other parts of the definitions of development are (c) the opening of a new market, (d) the conquest of a new source of supply of raw materials and intermediate inputs, and (e) the carrying out of the new organization of any industry.

15. And crucial economic institutions, including the firm.

16. I. Ehrlich, "The Problem of Innovation: Introduction, "*Journal of Political Economy*, October 1990, p. S7.

17. See W. Ethier, "National and International Returns to Scale in the Modern Theory of International Trade, "*American Economic Review*, 1982, pp. 389-405, for the first theoretical expression of this idea. Recently this has become one of the standard methods for deriving increasing returns based on long-run growth of productivity. See G. Grossman and E. Helpman, *Innovation and Growth in the World Economy*, Massachusetts Institute of Technology (MIT), 1991. For a discussion on the empirical evidence see, R. C. Feenstra, J. R. Markusen, and W. Zeile, "Accounting for Growth With New Inputs: Theory and Evidence, "*American Economic Review*, May 1992, pp. 415-421.

18. See the discussion on 'general purpose technologies' in Timothy F. Bresnahan and M. Trajtenberg, op. cit.

19. The ancient societies of Rome and China, for instance, were founts of spectacular technological advancement. For instance in the first century BC the city of Alexandria knew of virtually every form of machine gearing that is being used today, including a working steam engine. But very little of this was actually in use; the only use of the steam engine, for instance, was to open and close the doors of a temple. Similarly while the water mill, a major advance in the harnessing of power in the heyday of the Roman empire, was invented in the first century BC, it was not put

into general use until the fifth and sixth centuries AD. Similarly the technological precocity of the Chinese economy around the Sung period (960-1270 AD) was also most striking. Huge libraries, printing by moveable type, an extensive canal system, cannons and gunpowder, the compass, waterwheels, all existed during this period. However, this technological edge did not lead to a sustained rise in productivity and economic growth. There was again little incentive for widespread productive investment for this to happen.

20. Canada, Germany, Italy, Japan, the United Kingdom, and the US. See J. Bradford De Long, "Productivity Growth and Machinery Investment: A Long-Run Look, 1870-1980, "*The Journal of Economic History,* June 1992.

21. See J. B. De Long and Larry Summers, "Equipment Investment and Economic Growth, "*Quarterly Journal of Economics,* May 1991, pp. 1138-1154.

22. See N. Rosenberg and L. E. Birdzell, Jr., *How The West Grew Rich,* pp. 242-244.

23. G. Grossman and E. Helpman, *Innovation and Growth in the Global Economy,* p. 12.

24. See P. Romer, "Endogenous Technological Progress," *Journal of Political Economy,* October 1991.

25. R. J. Caballero and R. K. Lyon, "External Effects and Europe's Integration, "Columbia University, Department of Economics Discussion Paper Series No. 486, June 1990.

26. See Krugman, *Geography and Trade,* MIT Press, 1992, among others. The argument itself is a formalization of the famous theory of 'circular cumulative causation' developed earlier by Gunnar Myrdal.

27. Robert E. Evenson and Larry E. Westphal, "Technological Change and Technology Properties, "Asian Development Bank, mimeo, 1992, p. 2.

28. R. E. Evenson and L. E. Westphal, "Technological Change and Technology Properties," p. 2.

29. See K. Ohkawa and H. Rosovsky, *Japanese Economic Growth: Trend Acceleration in the Twentieth Century,* Stanford University, 1973.

30. See Moses Abramovitz, "Catching Up, Forging Ahead, and Falling Behind, "*Journal of Economic History,* June, 1986, pp. 385-406.

31. H. Pack and L. Westphal, "Industrial Strategy and Technological Change: Theory versus Reality, "*Journal of Development Economics*, 1986, p. 105.

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