Technological Change and Industrial Development
Issues and Opportunities

Frederick T. Moore

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Abstract

In this paper the importance of technological change in industrial development is explored, issues on which further study is required are identified, and directions for operational programs that could be effective in raising the level of technical capabilities in developing countries are indicated. Technological change is defined as the provision of new information or knowledge that is used effectively in industrial operations and has measurable effects on costs, product qualities, level of output or sales. The definition includes new information that improves the performance of management or labor.

The paper is in two parts. The first part considers principal issues in the relationship of technological change to growth and the substitution possibilities among factors, notably capital and labor. The theoretical and empirical economic literature contains extended analyses of many of the issues, and the design of effective development programs and projects depends a great deal on the validity of the conclusions of these analyses. Part two contains discussions concerning programs that are under way, with particular reference to the experience with several kinds of specific projects that are being implemented, particularly in the engineering or capital goods industries. This part also contains suggestions of ways of extending operations, revising policies and institutional arrangements, and making them more effective in promoting technological capabilities in industry.
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"International trade became an engine of growth in the Nineteenth Century, but this is not its proper role. The engine of growth should be technological change, with international trade serving as lubricating oil and not as fuel."

--Sir Arthur Lewis
Janeway Lectures, 1977

I. INTRODUCTION

1.01 This paper discusses the role of technological change in industrial development, identifies issues on which further study is required, and recommends operational programs and policies to improve technological capabilities in developing countries. The discussion focuses particularly on programs and policies that national governments could undertake to promote technological change.

1.02 The main issues of technological change as a source of growth and the inefficiencies that now exist in industry and that must be overcome if growth is to be sustained are discussed in Part One. This part is based on an evaluation of the findings and recommendations in theoretical and empirical studies in the economic and technical literature. These findings have direct implications for the design of development projects and policies.
1.03 Growth is dependent on improvements in technological capabilities as well as on increases in the amounts of the conventional factors of capital and labor. Particularly for middle-income developing countries that have come successfully through the early stages of industrialization and are facing challenges of increased specialization and product complexity the need to improve their grasp of technology and to lay the basis for continued progress is imperative. At present, many of the industries in these middle-income countries are not getting the most from their existing resources; costs remain high and their product qualities are not internationally competitive. The improvement of technology also raises a question of what choices among alternatives are appropriate to the circumstances and factor endowments that exist in these countries and what guidance can be derived from experience elsewhere. This issue has direct implications for the choice of technologies in the design of projects, since it is possible that varying proportions of capital, labor, and other inputs may change the prospects for the employment of labor.

1.04 Part Two covers key issues in the design and implementation of policies and programs for technological improvement. Only recently has the World Bank emphasized projects whose primary objective is to increase technological capabilities; the primary objective of most Bank projects remains that of capital deepening, which is another key and much better understood source of growth. In a growing number of countries, however, the mere expansion of the flow of investment funds into projects is not likely to yield expected rates of growth unless it is accompanied by programs to strengthen the ability of the recipients of these financial resources to use technology effectively and to take the necessary steps to
establish indigenous programs in this area. Part Two discusses in detail the formulation and effects of the policy framework, the difficulties of institutional controls, and related matters, before suggesting programs and policies that could be effective in improving technological capabilities in significant ways.

1.05 As a background to this report, two points should be specifically noted. First, technological change is not synonymous with a movement toward the most modern capital-intensive process. Changes occur through improvements in the efficiency in use of existing equipment—that is, through learning—and through the adaptation of other technologies, some of which may involve different equipment. There is a range of choices, and there are no reasons a priori for believing that the final choices will inevitably be the most advanced, computer-controlled type of technology.

1.06 Second, this paper is concerned with technological change in industry, but it should be obvious that a developing country will, or should, also be concerned about the prospects for growth through improved technology in other sectors—agriculture, construction, communications, and commerce. A number of the issues and some of the prescriptions for advancing technological capabilities in industry do, in fact, apply in other sectors, but it is not practical, in a single paper, to document the applications in all parts of an economy.

1.07 In this paper the engineering industries are cited as a special example because of their strong linkages internally and to most other
sectors. They are in fact the carriers of technological change and deserve special attention in development programs, but the problems and solutions are often shared by food processing, textiles, and other industries. We are concerned with the patterns and processes of technological change throughout industry, and the example of the engineering industries highlights many of the characteristics common to all industry.

1.08 The evidence on and state of knowledge of some of the issues discussed in the paper are still not conclusive and require further work; some accepted tenets of faith are questionable. But, equally, there are some directions for taking action that seem reasonable, although they are not as yet in the mainstream of thinking on the objectives and methods of development lending.

II. THE DEFINITION OF TECHNOLOGICAL CHANGE

2.01 It is probably impossible to set forth a precise definition of technological change that will satisfy all conditions or all people. It can be made so broad and inclusive that any single action seems trivial; not every act of investment, for example, necessarily involves a technological change. It may simply be the replication of a technology that is well known. On the other hand, if the definition is narrow it will admit only major innovations, which are rare and take a long time to be absorbed. Neither extreme seems desirable, particularly if there is strong interest attached to the policies and programs that can be designed to affect growth and development in a significant way.
2.02 The working definition adopted in this paper reflects an attempt to incorporate those elements that are observable, that have an effect on industrial production and operations, and that can be directly affected by policy choices or specific programs. Technological change is defined here as "the provision of new information or knowledge that is used effectively in industrial operations and has measurable effects on costs, product qualities, level of output or sales, and other ancillary operations of the firm." Several features of this definition can be noted; most important is that technological change involves the acquisition and use of new information or knowledge that affect production and sales of a product. This knowledge may be "embodied" in and accompany the introduction of a new piece of machinery, or it may be "disembodied" in the form of consulting services and technical assistance. If there is introduction of new machinery without the knowledge of how to use it efficiently—something that happens all too frequently in industries of developing countries—no change in operations will effectively take place, though, it is true, costs will be affected. It is a case of a technological change that is incomplete.

2.03 Although most changes are associated with production processes, the definition also includes the provision of new information that affects management, for example, in the control of inventories, costs, finance, or marketing. And it specifically includes the instruction of the worker on the production floor in the efficient use and operation of existing machinery as well as of new equipment.
2.04 A change of policy by the government will not necessarily bring about any technological change unless there exists local capability to respond to the signals that are being given. The emphasis on the flow of information, on training and technical assistance, is central to the notion of how technological changes occur or can be brought about.

PART ONE: TECHNOLOGY AND GROWTH: THE ISSUES

III. TECHNOLOGICAL CHANGE AND THE SOURCES OF GROWTH

3.01 The publication of Solow's (1957) article on the aggregate production function and technical change rekindled an interest in the relative importance of such change compared to the increase in capital per employed person as sources of growth. Total factor productivity is obviously influenced by a number of changes in the characteristics of inputs, and the economic literature contains a large number of articles and books intended to elaborate and refine the topic. Some have been stimulated directly by the Solow article (Kennedy and Thirlwall 1977), while others have proceeded from somewhat different methodological approaches but with the same purposes in mind (Denison 1962; Kuznets 1966; Salter 1966).

3.02 The central purpose of the studies is to decompose the sources of growth into separate, homogeneous elements and to measure the relative importance of each. The extent of the decomposition varies widely among the studies, but the element of technical change is common to all of them. Solow's article is simple yet perceptive in contrasting the growth of output that is ascribable to increases in the input of capital per man-hour
and that which is contributed by technological change. After testing for the neutrality of technological change, that is, that capital-labor substitution has not accounted for part of the growth (which seems to be satisfied), estimates are presented for the contribution of increased capital and technological change. For the period of 1909-49 (forty years) in the U.S., about 10-15% of growth is attributed to increased capital per man-hour and 85-90% to technological change. This is about 1.5% a year, of a total annual growth rate in output of 1.8% during this period.

A number of other studies have confirmed the importance of technological change as a source of growth, although the quantitative estimates sometimes differ. Massell (1960) made a similar analysis for U.S. manufacturing industry for 1919-55 and estimated that the annual rate of growth attributable to technological progress was approximately the same as Solow’s estimate. Denison decomposed the sources into a number of elements but concluded that about 40% of the total increase in per capita income between 1929 and 1957 in the U.S. was accounted for by technological change. Several other studies have arrived at estimates of total factor productivity in the neighborhood of 1.0-1.7% a year. Fraumeni and Jorgenson (1980) have estimated that in the U.S. in the years 1948-76 capital deepening was the most important factor to explain growth in value added, accounting for about 46% of the total, whereas technical change accounted for 33%, and the labor input 21%. For Japan during 1955-71, Nishimizu and Hulten (1978) arrived at a similar pattern, estimating that technical change accounted for 25% to 32% of the growth in value added but
that capital deepening accounted for 52% to 58%. Both studies used the same methodology which may underestimate the importance of technical change.\footnote{In both cases intermediate production is deducted from gross output to arrive at value added figures; yet intermediate production is a part of an industry's total production and is also affected by technical change. The deduction may thus lead to an underestimation of the importance of technical change.}

3.04 There have been objections to attributing to technological progress the high proportions of growth found in these studies. It can be argued that growth is not neutral—that is, that capital-labor substitution has occurred—that economies of scale have a measurable effect, that shifts in demand and production toward products that give evidence of higher factor productivity have occurred, and that expenditures on education and training are obviously important factors in accounting for the growth in output. For example, Denison separately calculates the effects of increases in education on growth. It should be noted that, according to the definition used in this paper, the effects of education and training would be included in technological change if they are directly related to the workplace and the jobs being done by the person, though indirect effects through increased education not directly related to the work are excluded. Thus, on-the-job training is included in this paper as one element but formal schooling is not.
3.05 Each of the above criticisms or reservations may be valid, to a greater or lesser degree, and thus cause a modification of the conclusions about the magnitude of the influence of technological change, but despite whatever adjustments this may entail, the fact that technological change is an important explanation of growth in output is not substantially diminished. It may not be 90% of the explanation, but even if it is half that, the conclusion with regard to the importance of technological change holds good. On the basis of his extensive analysis, Kuznets (1966) concludes that "modern economic growth could best be viewed as a process based on a complex of additions to useful knowledge," and Nelson and Winter (1974) emphasize that "the essential forces of growth are innovation and selection, with augmentation of capital stocks more or less tied to these processes." There is, however, a need for further theoretical and empirical studies to permit more precise evaluations and conclusions on the role of technological change as a source of growth; Arrow (1962) has observed that "the concept of knowledge which underlies the production function at any moment needs analysis."

3.06 Another aspect of the measurement of technological change also has generated some discussion. It concerns the importance of "embodied" change in relation to that of "disembodied" change. The latter refers to increases in productivity that are not associated with changes in the input of capital. Some increases can occur through the application of new information to an existing stock of capital; this has been analyzed in terms of the "learning curve," whereas "embodied" technological change is that associated with new investment and the introduction of new or different machinery and equipment.
There are studies that clearly point to the significance of
increases attributable to disembodied knowledge, particularly in the short
run, since presumably the ability to increase productivity from existing
capital has an upper bound and the increases are realized within a short
period.\footnote{But see also the cases of the Western Electric Hawthorne experiments and the case of the Swedish Horndal steel plant where productivity increased throughout a long period without new investment (Leibenstein 1976).} Normally, however, technological progress occurs in conjunction
with increases and changes in capital equipment. Solow made this point in
his 1957 article, and others have attempted measurements of the relative
importance of the two kinds of change. Mansfield (1968) made calculations
for ten large chemical and petroleum firms and concluded that embodied
technological change was much more important in accounting for growth than
"disembodied," ranging from 10\% to 900\% greater. A later study by Solow
involving calculations of embodied change raised his earlier estimate of
1.5\% annual increase (based on disembodied change) to 2.5\% annual rate
(embodied change).

It is logical to assume a priori that technological progress will
be associated with changes in capital; even in the short run some
incremental changes in investment in individual pieces of equipment to
break bottlenecks do occur. Training of labor and management on the
job--disembodied change--can significantly increase "learning," and in most
actual cases both types of change are apt to be present and to interact

3.09 Virtually all the studies that have been conducted are for the
U.S., Western Europe, or Japan for periods during the present century,
when, however, many of these countries were undergoing rapid changes in
technology and industrial structure. These studies do not refer explicitly
to the developing countries of today; yet the middle-income, or newly
industrializing, countries are also entering or are in mid course of rapid
industrial change. This, for example, is reflected in the growth of
manufactured output and increased exports of non-traditional goods—
particularly in the rapid growth of capital goods (machinery and
equipment)—which are leading to considerable shifts in the structural
composition of industry. The shifts are toward industries in which:
(a) technological changes will increase in extent and importance; and
(b) mastery of more complex technologies and the ability to adapt them will
essentially determine success (Balassa 1981, 1980a, 1980b, 1980c; Cody and
others 1980; Lydall 1980; Patel 1980; UNIDO 1980b; United Nations 1979; and
Zaleski 1980).

3.10 At present industry accounts for almost 40% of the gross domestic
product of the middle-income countries and has been growing rapidly. The
structure of trade is also undergoing significant changes with relatively
sharp shifts toward manufactured goods, particularly engineering products,
and the rate of growth in volume has been increasing. Lydall (1980) has
estimated that the average annual rate of growth in developing countries' exports of capital-intensive products—mainly chemicals plus machinery and
equipment—was more than 45% during 1970-74 but only 16% during the
preceding decade. This presents a contrast to much slower rates of growth in the value of exports of labor-intensive goods, which are estimated at 29% during 1970-74 and 13% during 1960-70. Balassa (1980b) has estimated that the share of imports of engineering products in total imports of the industrial countries from developing countries will rise from 30% in 1978 to 48% by 1990, and the developing countries are expected to more than triple their imports of engineering products from the industrial countries in the same period. These products are expected to increase their share of total trade in manufactures (imports plus exports) between industrial and developing countries from 57% in 1978 to 77% by 1990.

3.11 Such estimates are based on the assumption that the quality, volumes, and prices of the products originating in developing countries will meet international market standards, although countries most advanced in the production of engineering goods are exhibiting some serious deficiencies. Technological improvements in the developing countries are required if the growth forecasts are to prove accurate, and that will come about only if there are specific programs to increase present technological capabilities.

3.12 There is a need for detailed analyses of the relative importance of technological change as a source of growth in developing countries and an identification of the policies that could prove effective in supporting and stimulating the efforts of domestic firms to improve their technological capabilities. These issues have not been adequately explored in the economic and technical literature, even though the design of development programs might be significantly affected by the results of such analyses. It is reasonable to suppose that the relative importance of
technological change may vary for countries at different stages of
development and among industries at each stage. The topic is complex and
might be approached in a number of ways. For example, we might hypothesize
that in an early stage of development when incomes are low, capital
widening and deepening may be the most important single factor, whereas at
later stages the influence of technological improvements might become
dominant. If this proves to be so, the choice of policies by governments
and the design of projects would change as development proceeds. This
might require, at some stage, a shift in emphasis in the development
program to search out means of supporting projects whose main objective is
improvement in technological capabilities.

IV. CHOICE OF TECHNOLOGY AND FACTOR PROPORTIONS

4.01 The concern with technological progress as a source of growth has
taken second place in the economic literature to a concern with the choice
of technology—or, more generally, efficiency in the allocation of
resources—at the level of the firm and the possibilities for substitution
among the factors, particularly the substitution of labor for capital.
This stems from the concern with providing employment to growing
populations in the developing countries; the greater the substitution
possibilities, the greater will be the ability of the industrial sector to
absorb labor.

4.02 There have been two ends to the spectrum in the debate. One end
is represented by the position that there are no substitution
possibilities. Production uses factors and other inputs in fixed
proportions; the isoquant for capital and labor is a right-angle. This is
the assumption in input-output models and in some (but not all) process
models. The other end of the spectrum is represented by those
who maintain that there are extensive substitution possibilities; the
isoquant is relatively flat, and only slightly convex to the axes. It is
relatively easy to substitute small amounts of one factor for another as
factor prices shift slightly.

4.03 In this context, several points should be noted. First, the
question of substitution and choice of technology applies primarily to
investment in a new plant, a "green field" type of project. Once an
investment has been made and the problem is one of additions or
modifications to an existing plant, the possibilities for substitution are
much more limited. The existing technology and equipment sharply limit the
choices that can be made. The investor is locked in and has to adapt
expansion investment to the technology that exists. An industry can change
its structure and factor proportions if new entrants to the industry use a
different—for example, a more labor-intensive—technology than existing
plants, assuming that there is a range of factor combinations that are
equally efficient. The result would be an industry with plants of various
kinds and sizes, involving quite different types of technology. For some
kinds of industry—some machinery industry, for example—that phenomenon can
be observed in practice, whereas, for other kinds, such as some chemical
industries, it is not common.

4.04 Second, the choice of technology normally refers to uses of
primary factors—that is, all varieties of capital equipment and all
classes of labor. It may also refer to inputs of raw materials and
intermediate products. Substitutions can occur in such inputs—aluminum
substitutes for steel, or plastics for wood, for example—but it is assumed
that the end products of alternative technologies that are being compared
are close substitutes—in theory, perfect substitutes. This conclusion gives rise to a number of difficulties and is the source of a significant part of the differences of opinion on technology among some participants in the debate. What is a "close" substitute? Is handmade soap a close substitute for a manufactured detergent? Or a hand saw for a circular power saw? Whether products are close substitutes depends on the cross-elasticity of demand. There are no agreed values as to what constitutes a close, as opposed to a distant, substitute. From the point of view of the consumer or user the question is whether the products provide equal satisfaction or have equal capabilities, as in machinery. In the overwhelming number of cases, qualities do differ from one product to another. Also, among most engineering products, but also including other types of products, even when technical characteristics and prices are the same for two products one of them may be preferred to the other because after-sales service is better. The service is essentially part of the product. In many other ways products are differentiated in the market.

4.05 There are some who argue that the definition of "product" in a consideration of choice of technology should be deliberately wide, not constrained by the question of close substitutes, because to constrain it so almost automatically excludes many of the simpler—that is, appropriate or labor-intensive—products and techniques from the market. Some analysts argue that if products were specifically designed for the poor countries, they would differ greatly from those produced by the industrial countries and consequently the technologies would differ and be much simpler and more labor-intensive (Stewart 1977; Stewart and others 1974; Baron 1980). According to this point of view, the failure is in the market mechanisms,
because of the concentration of income and purchasing power in a small part of the population and the ineffectiveness of government policies to promote the technologies appropriate to the cultural, economic, and institutional conditions in the poor countries. In short, the problems of the choice of technology are that the environment has never been favorable to the development and adoption of appropriate technologies, and if it were, the results would be far-reaching and affect the whole operation of an economy. To quote Stewart:

The introduction of a more appropriate technology would reduce the large disparities in control over resources, labour productivity and income distribution ... imbalance in employment opportunities, the appearance of open unemployment as a chronic problem, and maldistribution of income—should disappear (Stewart 1977).

4.06 Whatever sympathetic echoes this line of argument evokes, the fact is that it stretches the problem of choice of technology to the breaking point. If there are imperfections or distortions in the market demand, if consumers are irrational in preferring modern manufactured goods, if government policies discriminate against simpler, home-grown products and technologies, there are corrective actions that can be taken, but it is manifestly unmanageable to label these as problems in the choice of technology. Choice is made in response to the demand and to market conditions. If we are going to compare alternatives to determine whether technologies permit substitution among factors, it is necessary to define the problem in terms of the production of close substitutes. That still leaves room for some degree of product differentiation.
4.07 At the extreme, the above argument comes close to asserting that consumers in developing countries should not want nor be permitted to choose a "modern" product over a "traditional" one. Palm wine is permissible; never mind Heineken beer. Since the former is produced domestically and the latter is imported, the argument is that domestic production should be stimulated and imports limited. Although import controls are a proper concern of government, the implication that technology choices should be made on the basis of moral judgments as to what consumers "ought" to want cannot be supported.

4.08 Third, the treatment of technological choice should at best be neutral with respect to the issue of technological progress and the contribution to growth. The analyses reviewed below do not discuss whether one type of technology is apt to have greater potential for future adaptation and acceleration of growth than another type. Whether capital-intensive or labor-intensive configurations in an industry are more conducive to later adaptation, innovation, and growth is an issue that does not appear to have been addressed. Yet it is clearly an issue of importance to a developing country that is concerned not only with the efficiency of its industrial structure and the technologies it includes but also with the potential for growth from industry in the future. To understand the process of innovation and growth a different starting point, that of the activities of research, development and engineering (RD&E) of new products and processes, is appropriate. Some aspects of these activities are considered later.
4.09 Whether different types of technology are apt to be more or less conducive to growth, depends on the extent of linkages, both backward to suppliers and forward to the market. Different industries exhibit different degrees of the extent of these linkages. One hypothesis asserts that capital-intensive firms or industries tend to have stronger linkage effects than do labor-intensive ones; the indirect effects are greater. Stern and Lewis (1980) have calculated the direct and indirect effects on output and employment and their results seem to indicate that the indirect effects of capital-intensive industries are extensive. The aggregation of the data in the input-output models used, where both capital-intensive and labor-intensive firms are included in the same aggregated "industry", may limit the conclusions that can be drawn.

4.10 Finally, it is important to note that in analyses of the limitations on choice of technology, only occasionally is the minimum efficient size (MES) of plant considered. Comparisons are made of production costs of specific technologies to arrive at judgments as to their relative efficiencies, and size of plant is implicit or explicit in the calculations, but the analyses do not consider whether the long-run average cost curve is "flat-bottomed"—that is, whether plants of different sizes and different technologies are about equally efficient throughout a range of output. Yet, for investment decisions it is important to know the characteristics of the minimum efficient size of plant. This is a topic that warrants further analysis.

4.11 The remaining paragraphs in this section review the empirical studies and evaluate the guidance for operational decision making that may be derived from them. The studies that have been made are classified in
two groups: (1) econometric analyses of the production function, to derive
the elasticity of substitution between the factors of capital and labor;
and (2) specific case studies of technological choices to produce
particular products.\(^3\)

Econometric Analyses

4.12 There are many problems involved in using the production function
to estimate substitution possibilities between capital and labor, chief
among them are: the definition of the factors and the choice of the
statistical series to represent them; the aggregation of the industrial
classification (theoretically only firms producing close substitutes should
be included in the sample; product heterogeneity vitiates the statistical
results); the inclusion of only two factors, capital and labor, without
distinction among types of capital or degrees of labor skills, which masks
some of the potentially most interesting of factor trade-offs. There are
other problems in the econometric analyses of the production function, many
of a mathematical or statistical kind. One problem deserving special
mention is the assumption that all of the firms in the sample have access
to the same technological choices and that for the one that is chosen each

\(^3\) For surveys see Acharya (1974), Morawetz (1976), and Pack (1980b,
firm realizes the maximum output from the given factor mix; that is, it is assumed that each firm is on the production frontier. As will be shown later, this assumption is in many cases faulty; the opportunity to increase output and productivity from existing factors—that is, to reduce X-inefficiency—is both widespread and a primary source of technological improvements and progress in industry.

4.13 Acharya (1974) reviewed the results of about ten econometric studies, and Morawetz (1976) made several types of comparisons of 12 sets of data for the U.S. and four for developing countries, at the two-digit industry level of classification. A number of the same studies were covered by both reviewers. The results of the studies varied widely. Of those reviewed by Morawetz, the great majority calculated the elasticity of substitution at less than one, with some about zero, which indicates that no substitution is feasible. Few of the calculated values based on plant-level data were greater than one, which would indicate relative ease of substitution. Morawetz hypothesized that if the studies are to serve as guides, they should show consistency in the ranking of industries according to their calculated elasticities in the various studies. Rank correlation coefficients were calculated for six pairs of developing-country estimates; four of them were not significantly different from zero, one was significantly positive, and one was significantly negative. The results are clearly inconsistent.

4.14 After a review of all the evidence Morawetz concludes that the econometric studies "do not help in identifying industries which have relatively high or low substitution elasticities" and Acharya also agrees that "sectoral CES production function estimates of the elasticity
parameter are unlikely to be reliable guides to potential factor substitution possibilities." It is well to remember, however, that these criticisms do not necessarily impugn econometric investigations per se, but only the studies that were reviewed. If the difficulties discussed above could be avoided or mitigated, if studies were done more carefully on disaggregated data, they might yet provide some better or more reliable answers than they have so far.

Specific Case Studies

4.15 The individual case studies of specific products have avoided many of the limitations of the econometric investigations but at some cost in generality. The investigators are able to explore, in detail, the production processes that are available—or that are regarded as feasible even if no exact examples are found in the market—and can consider different kinds of factor inputs—such as types of labor and capital. To study these products adequately, however, requires a great deal of painstaking work, so the coverage of products and industries is limited. There are many kinds of products, in the larger industries, that have not been studied. The sample represented by published materials is limited; nevertheless, some common threads and tentative conclusions are to be found overall.

4.16 As described earlier, the basic question is whether fixed proportions—elasticity of substitution of zero—predominate throughout industry, as has commonly been maintained, or whether there is scope for substitution among factors, in response to changes in factor prices. Many of the studies conclude that substitution is feasible, on a fairly wide range of products, that the alternative labor-intensive techniques are well
known and frequently have existed, and continue to exist, in the country-side, and that they often appear to be superior—that is, lower in cost—to modern manufacturing technologies that are more capital-intensive. Some of the investigators think the results are so clear that it is no longer tenable to maintain the position that production in industry is largely governed by fixed proportions. Pickett (1977) in summarizing significant conclusions of the extensive studies of the Strathclyde group, says that "the demolition of the previously prevalent notion of technological determinism is probably the most secure result of the studies to date," and Baron (1980) echoes this sentiment in summarizing later studies in food processing in saying that the work "completes the task of demolition." Although much of the evidence is in favor of the existence of efficient factor substitution for a number of products and the burden of proof to the contrary is on those who maintain the dominance of fixed proportions, it is too early, and the evidence too sketchy, to talk of "demolition" of the proposition of fixed proportions.

4.17 The number of products included in the empirical studies is extensive, but the coverage of industries is distinctly limited. A representative listing, with no attempt at being exhaustive, includes:

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cotton textiles, food processing (e.g., rice and maize milling, baking, coconut oil, milk processing, sugar-cane processing, beer, fruit and vegetable preservation, and fish preservation) canmaking, cement blocks, nuts and bolts, iron foundry, selected metalworking equipment, leather goods, bricks, and corrugated board and boxes. Coverage of products in the studies appears to be concentrated on consumer goods, those simpler or homogeneous in character, and mainly in light industry; coverage is scanty or absent for products in the chemicals, transport equipment, basic metals, fabricated metal products, electrical and mechanical equipment, rubber, and pulp and paper industries. Stewart (1977) speculates that "it is likely (studies were) only initiated where there was a prior presumption that a range of technologies did exist. The industries listed are generally speaking old industries so that old vintages from the advanced countries and/or traditional techniques in poor countries provide labour-intensive alternatives to the latest techniques."

4.18 The most extensive coverage of products in an attempt to define the limits of factor substitution is that by Forsyth, McBain, and Solomon (1980). They define an "index of technical rigidity," (ITR) which can take values ranging from eight—that is, little or no substitution possible—down to zero (easy substitution) on the basis of eight physical barriers to substitution of labor for capital. These barriers to labor use are associated with the following factors: high or low process temperatures; presence of fluids; application of fluid pressure on materials; need for high-speed operations; necessity of close tolerances; use of electric power and high load factors; involvement of indivisible heavy materials; and special hazards. They scored 181 products commonly produced in developing
countries as well as in industrial countries. Their results give some support to the argument of potential substitution or flexibility in the use of labor in a number of products. There are only 13 products that have an ITR as high as 6 or 7 (little substitution) but 87 with an ITR of 1 or 2 (easy substitution). No attempt was made to distinguish the importance of products according to values of output. Although criticisms can be made of the concept and measurement of the ITR, it has merit as a screening device and as a means of making comparisons across a number of products.

4.19 There are a number of conditions in production that may severely restrict the substitution of labor for capital. One of these is the existence of economies of scale. These exist when at least several of the following conditions prevail: a standardized product involving well-defined processes in cutting, machining, forming, and assembly; the lot size or average production run of one model is lengthy; tolerances are "high", but no extensive continuous calibration or testing is required; processing is simple and involves bulk materials. In some respects, but not all, the conditions for economies of scale are similar to some of the factors used by Forsyth, McBain, and Solomon to define technical rigidity. The classic example, often cited, in which economies of scale are exceedingly important is the processing of basic metals, but there are many others.

4.20 As mentioned earlier, in the empirical studies of factor substitution the questions of economies of scale and minimum efficient sizes of plant are typically not explored. Pack (1980) believes that, on the whole, the studies of the production function do not indicate a strong tendency favoring capital-intensive technologies as output levels increase,
but that may be due to the limits of the products covered in these studies, and on the demand side he admits that "as national market size grows, the scope for efficient use of labor is diminished."

4.21 Even if the core processes in a plant are technologically determined, it is possible that ancillary processes do lend themselves readily to substitution of labor for capital. The process most commonly mentioned is materials handling or transfer. Another not so commonly mentioned is the substitution of labor for fractional-horsepower motors (and electricity) in the working of levers or other devices in a planar or rotary fashion. In the existing empirical studies the possibility that process areas may differ significantly in their acceptance of substitution are not explored; consequently, no useful conclusions on this subject can as yet be drawn.

4.22 Of course, if the long-run average cost curve is flat-bottomed, there is a range of efficient sizes of plant operations and at the lower end of the range may be found the so-called small-scale enterprises (SSEs) in some product lines. Typically, the data from censuses and other sources tend to indicate that capital-labor ratios in SSEs are much lower than in large enterprises, which means that the employment absorption per dollar invested is higher. In a detailed study of SSE in Taiwan and in the Republic of Korea, however, Ho (1980) found that the capital-labor ratios in many Korean industries do not rise with increases in the size of the establishment and that "low-volume techniques do not always have capital saving attributes." He concluded, in general, that "few small establishments in the 5-49 workers range are efficient."
4.23 What are we to believe from a review of the empirical studies of choice of technology and factor substitution? Where does the debate stand? The evidence is ambiguous, contradictory, and does not admit of simple propositions. The fact is, it all depends,—on the industry, the product characteristics, market conditions, entrepreneurial talents, institutional factors, and undoubtedly other aspects that could be distinguished. Factor substitution is alive and well and living in some product lines, but technological determinism is not dead—at least in some industries.

4.24 What is impressive—and quite surprising—to the reviewer of these studies is the paucity of "hard," credible evidence in what is, perhaps rightfully, regarded as an extensive literature. There are, of course, notable exceptions; some of the studies could serve as models. But there is still a long way to go, quantitatively and qualitatively, to obtain the coverage and the comprehensiveness. Still, on a case-by-case or industry-by-industry basis it is feasible to choose and support activities that take advantage of substitution possibilities and, most important, advance technological progress and growth.

Employment Implications

4.25 Continued concern with technological choices and prospects for substitution of labor for capital is based on the necessity of providing employment for a growing labor force and increasing incomes through increases in productivity. If substitution possibilities are widespread throughout industry, as has been assumed, the microeconomic effects of substitution of labor-intensive technologies for ones that are more capital-intensive might be substantial.
4.26 The empirical studies that focus explicitly on the expansion of employment opportunities resulting from changes in technology are limited in coverage and differ somewhat among themselves in their conclusions. In his review of employment implications of industrialization, Morawitz (1974) was able to find only three systematic studies that dealt with this topic. In general, they assumed that technical choices would shift toward labor-intensive methods if these existed or traced out the effects on employment of shifts in output or consumption toward labor-intensive products. Although the studies had defects, it was tentatively concluded that employment effects might be significant.

4.27 A further study assumed an "economy" made up of plants in nine selected industries where the feasibility of labor-intensive production methods previously had been shown to exist. If investment in these industries expands, employment might increase substantially over what would result if capital-intensive methods were used (Pack, 1980b). But a series of studies of food processing industries are not so optimistic about the prospects for increases in employment from shifts toward labor-intensive technologies (Baron, 1980).

4.28 If it is assumed that substitution possibilities are widespread, the questions that naturally come to mind are: If this is so, what prevents even greater and more obvious shifts to these simpler technologies? Why is there a current of belief that these shifts are being frustrated? Several possible answers have been offered.
First, and perhaps most important, government policies in developing countries often have created a bias toward capital-intensive investment. Through low customs duties and excise taxes on capital goods imports, tax holidays, preferential access to credit, and similar policies, an environment favorable to capital-intensive investment is created. These are reinforced by policies and laws intended primarily for their welfare effects but that may inhibit labor-intensive choices—minimum wages set higher than productivity prices, for example, restrictions on firing, commitments on retention, and large fringe benefits. There is general agreement that, whatever the intentions were, the actual effect of many industrial policies in the developing countries is to favor capital-intensive choices. Their effect is to alter the structure of industry, but that does not necessarily mean that they have brought about the dominance, throughout all industry, of capital intensity in technological choices.

Second, the blame for the bias is sometimes laid at the door of transnational corporations (TNCs). They are presumed to transfer, without change, the capital-intensive techniques of industrial countries to the developing countries because they are familiar with these techniques, they know how to manage and operate them, and to redesign the plants would be costly. Some studies seem to support this argument. Forsyth and Solomon (1977) compared investment behavior in Ghana of TNCs in Ghana, plants owned by expatriates resident in Ghana, and indigenous firms. Their results indicated that the first two groups reacted similarly and differently from the indigenous firms, which had lower capital-labor ratios. Lecraw (1977) arrived at similar conclusions based on analyses of 200 firms in Thailand. But other analysts have come to opposite conclusions. Pack (1980b, 1979)
speculated that TNCs, as rational profit-maximizers and with the knowledge of alternatives, use more labor than indigenous firms. A survey by Lall (1981) led him to conclude that there is no strong evidence that TNCs adapt either better or worse than local firms to changes in factor prices, and in a second study of the behavior of subsidiaries of Unilever he found that the capital per employee in developing countries was less than half that found in industrial countries (Baron 1980). Frank (1980) undertook extensive interviews with TNCs in the U.S. and Western Europe and found that they do adapt to local conditions, particularly in response to low labor rates. Where the TNCs had not done so, some subsidiaries were closed. Morley and Smith (1977) found evidence in metalworking industries in Brazil that TNCs did adapt to local factor prices. In short, these studies do not demonstrate the presumed culpability of the TNCs.

Third, the argument is sometimes made that the concentration of income and wealth, the framework of policies, laws, institutions, and vested interests that support the concentration, lead both to a distortion of market demand in favor of modern goods and to limitations on the growth of simpler technical supply conditions. There is a conjunction of influences that cannot be changed piecemeal. To even begin to explore this position would take us beyond the bounds of this paper. It is mentioned purely for the purpose of identifying an end point in the class of arguments that is made on this topic.

Finally, the lack of a shift to simpler techniques and effective use of them may be attributable to a lack of information on technological choices and an inability to use existing ones efficiently. This is an aspect of X-inefficiency and will be discussed in the following section.
No general judgement, applicable to all industries, on the prospects for employment creation (and increases in income) through shifts to labor-intensive technology can be made based on the existing studies. Some of the evidence from the studies is favorable and holds forth promise for greater labor absorption, but the coverage of industries is limited, and the existing studies of the macro effects have a number of defects. In individual cases, however, it should be possible to determine the economic prospects for substitution and, if they exist, to take advantage of them in the interests of expanding employment opportunities.

V. THE PREVALENCE OF X-INEFFICIENCY

As noted earlier, in econometric evaluations of the production function, and in some microeconomic studies as well, it is assumed that the firms are on the frontier of the production possibility surface or the isoquant (in the two factor case). This means that the firm is able to realize the maximum output that is technically feasible from the given combination of factors. Existing resources are used efficiently, and if new investment is made in capital equipment and more labor is hired, the firm is assumed to move to a higher efficient point. However, in order to produce efficiently, the firm must have the technical and economic knowledge of organization and management of production facilities and must also have information about alternative production functions. If the firm is off the isoquant, a smaller output is obtained than is possible with the resources costs are therefore higher, and frequently there is some degradation in the quality of the product. This reduces the ability to compete in the market.
5.02  The usual assumptions that firms are operating on the frontier, that they have the knowledge to use their resources efficiently, and that they have access to information and can make correct decisions on new machinery and equipment are not borne out by the evidence. The opposite is more nearly true; there are typically inefficiencies in the use of resources, compared to "best practice," and the selection of new equipment is frequently faulty. X-inefficiency is prevalent throughout many industries in the developing countries—and in industrial countries as well. The existence of these conditions is partly traceable to the lack of appropriate technical and other information and to the real costs of acquiring it. There are, consequently, welfare losses to the economy—and to the firms, obviously—and technological progress is retarded. Corrections can be made through technical assistance and training.

5.03  Leibenstein (1976, 1969, 1957) who has done the most to develop the concept of X-inefficiency and to explore its consequences, has identified a number of possible reasons why firms may not produce on the efficient frontier. Chief among these is the lack of information about the alternative production possibilities. Nelson (1972) states the case quite forcefully:

One would expect to find firms often having neither articulate reasons nor appeals to experience to justify what they are doing and indeed being somewhat nervous about it. It certainly seems inappropriate to view behavior as being objectively rational in any non-trivial sense . . . it seems a
bad misspecification to assume that a firm has access—over the relevant analytical period—to any technology to which any other firm has access.

5.04 The production function is not fully known by the firm, nor is its own objective function fully articulated or understood. The firm does not necessarily act, as neo-classical theory assumes, in an optimal fashion. Not only are there gaps in knowledge of production techniques, particularly in the engineering industries, but it may be costly to acquire the information, and there may even be ignorance of the reliability of the sources. The sellers of machinery do not act from altruistic motives to help the buyer decide what is really best for him. Leibenstein notes that one result is that developing countries may be "locked-in" to certain techniques and "locked-out" of others, so that once a production line is organized, it is difficult to make significant changes.

5.05 It is also true that some firms are averse to risk and will make changes slowly and only when compelled to do so by competition or through the overwhelming evidence that a change will lead to a better position. Traditional work habits that are inefficient develop in both management and the operating labor force; there is inertia to be overcome before changes will be made. This is amply illustrated in the following case observed by a World Bank mission in Korea. A new machine for induction hardening along a drive shaft was being installed by a foreign engineer. The labor crew was operating the machine very slowly and the engineer explained:

That (machine) will do that four times as fast and it's going to. However ... they have been doing that shaft by another hardening machine at a certain rate and they refuse to do that any
faster and they're afraid that it won't work. All I have to do is when I feel they've got the swing of things I go and get the superintendent who is a wonderful fellow and then I run the machine showing them how fast it will go and they all watch it and believe it, and when he gives them the word, and only when he gives them the word, then that thing will be up to four times the speed ... but if I left them alone this new machine will be run at the same speed and in the same mode (that) they are accustomed to doing (World Bank, 1979).

5.06 Clinging to traditional work methods is not the only source of inefficiency. The layout of the machinery and flow of work, lack of maintenance, and poor operating practices are of equal, or greater, importance in the total effect. As one engineer noted following a plant visit:

I have never in my life been in a shop ... wherein anyone in the management of the company with any knowledge of manufacturing could walk through the shops which I had just seen in operation and allow these machines to be operated under the present conditions for more than one hour. The best machine tools on earth for performing the simple machining and threading operations ... would cease to function within 60 days if they were used under the same conditions as their present equipment ... if this shop were located near my business, I could go into it, if given blanket
authority to do what is necessary, and with about six good machine
tool repairmen, clean it, improve productivity and product quality
by 100%, and show their people how to keep it running at that rate
for several years.

5.07 There is accumulating evidence that not only is X-inefficiency
prevalent in much of the industry in developing countries but also that the
correction of it would improve competitive positions and provide a better
basis for further technological progress. In citing a study by Kilby of
selected manufacturing activities in seven countries, Leibenstein (1976)
notes that cost reductions of 25 percent or greater could be achieved, and
he argues that the benefits to the economy from correction of X-ineffici-
ency are apt to be much greater than those achievable from better alloca-
tion of investment. The latter assertion is based on estimates of the
welfare effects of redistributing investment in customs unions compared to
the findings on X-inefficiency in industry.

5.08 Some of the most recent, and most specific, evidence on this
problem is in several World Bank reports. Many industrial sector reports
have noted the existence of X-inefficiency but the ramifications were not
always explored. There are several sector reports on the engineering
industries that bear directly on the issue. They include work on Korea,
Thailand, Indonesia, Mexico, Morocco, Tunisia, and Argentina.

5.09 On the basis of visits to a sample of plants, evaluations were
made of the technical capabilities of the plants and their competitive
positions. The evaluations included specific attention to seven functional
areas: the plant layout and flow of work; operating practices in
production; maintenance programs; product qualities; the capability to do
product adaptation, design, and testing; the use of labor and its effects on productivity; and management. In each area, the plant was given a score comparing it to efficient practice in industrial countries. The results clearly indicate the extent and the principal sources of inefficiency in the use of existing resources. For example, among Thai firms the overall score of the plants that either involved joint ventures or had technical engineering skills in management were significantly higher than those of Thai firms that did not have these skills. This is an indication of the importance of technical information and competence in the competitiveness of industrial firms. The aggregate (weighted) scores were as follows (a score of about 90-95 represents efficient practice in industrial countries).

<table>
<thead>
<tr>
<th>Type of firm</th>
<th>Score</th>
<th>Interpretation</th>
</tr>
</thead>
<tbody>
<tr>
<td>Thai firms without engineers</td>
<td>72.0</td>
<td>Unsatisfactory; serious deficiencies.</td>
</tr>
<tr>
<td>Thai firms with engineers</td>
<td>81.6</td>
<td>Acceptable for expansion in local market.</td>
</tr>
<tr>
<td>Joint ventures</td>
<td>84.3</td>
<td>Acceptable for local market; may be able to export.</td>
</tr>
</tbody>
</table>

The differences among the scores are associated with differences in the command of information. Joint ventures are usually, but not invariably, in the best position. Their technologies, plant, and equipment are designed by the foreign partner but even so they do not uniformly score well on engineering design and adaptation of products; that function is frequently
reserved by the foreign partner. The diagnosis of the sources of inefficiency in these reports is followed by preliminary prescription of actions needed to correct operations so that the firm can attain a comparative advantage in relation to imports. In several countries this has led to the initiation of World Bank projects that will assist in the structural adjustment of the industries and an improvement in their technological and competitive positions.

5.10 All the studies of X-inefficiency stress, in one way or another, the importance of the flow and absorption of information on technological choices as a means to overcome the deficiencies. Some of them also consider the kinds of assistance and training that are likely to be effective, including self-help by the firms that are involved. In summarizing conclusions derived from Latin American studies, Sercovich (1980a) has stated the case succinctly:

The possession of information is the key factor in the negotiation of technology: information destroys what has been called a virtual monopoly, due to the misinformation of buyers. Information permits the modernization of the technological art.

5.11 It is not only, or perhaps even primarily, the possession of information that is of practical importance but rather the use that is made of it by firms in the developing countries. Westphal and his colleagues have stressed the importance of the mastery of technology, since it takes time and a series of incremental adaptive changes before a technology is fully and effectively used (Dahlman and Westphal 1981; Westphal, Rhee, and Pursell 1980, 1979; Rhee and Westphal 1977). Studies made in Latin
American countries have also confirmed this thesis (Katz 1978; Sercovich 1980; Sercovich 1980a, 1980b, 1978). For example, Korea has progressed through the efforts of indigenous entrepreneurs and has not relied heavily on direct foreign investment nor licensing. It has been the slow, step-by-step learning and adaptation of technology that has produced results. As stated by these authors, "technological mastery in practice is more a function of indigenous problem-solving at the plant level than of acquiring ready-made experience from abroad," and it is concluded that "a sequence of minor technological changes can have a pronounced cumulative effect on productivity" (Dahlman and Westphal 1981). In this way, X-inefficiency in the plants can be effectively reduced.

5.12 The existence of inefficiency and the lack of technological mastery pose two challenges to policy makers: (1) to design programs that will lead to efficient use of existing resources, including adjustments in current practices, and (2) to establish a basis in RD&E activities that are appropriate to the environment in the country, so that progress can be maintained, at least to the extent of creating informed buyers. The remainder of this paper is devoted to these issues.

PART TWO: POLICIES AND PROGRAMS FOR TECHNOLOGICAL IMPROVEMENT

This part of the report is concerned with formulation of policies and the design of projects to enhance the technological capabilities of developing countries. Two major points will emerge from the following discussion. First, neither governments nor the Bank (nor other international or bilateral lending agencies) have substantial experience of technology development programs, since the emphasis so far
has been primarily on capital deepening projects; nevertheless, in the past several years there have been several projects that are specifically aimed at improving technological capabilities, and this experience is growing. For the reasons presented in Part I there should be even greater emphasis on technological development in the future. Second, the recommendations discussed below do not apply equally to all developing countries. They apply mainly to middle income countries or to countries with relatively large industrial sectors. They are less relevant to other countries, such as those in sub-Saharan Africa and low income countries that are in early stages of development, although some steps to improve technology are clearly applicable, and should be pursued (e.g., upgrading training in selected technologies).

VI. THE ACQUISITION AND COST OF TECHNOLOGY

6.01 Most developing countries are initially dependent for their technological apparatus on the industrialized countries. This is evident from a review of the trade in machinery, which is one indicator of technology flow, the extent of licenses, including access to patents, for processes and products, and other similar data. Nevertheless, some changes are occurring that will in time lessen the degree of dependence, and some developing countries are already exporters of technology in their own right.

6.02 As a result of technological development in a number of countries, the structure of trade between developing and industrial countries is shifting; growth of exports from developing countries is expected to
continue to be rapid in engineering products (Balassa 1980b, 1980a, 1979). Lall (1981) has analyzed exports of technology from India and Dahlman (1980) has presented the results of a pilot study of Brazil and Mexico. Obviously, the existence of exports demonstrates that a country has a sufficient degree of technological sophistication to be able to provide specialized services, sales of equipment, and turnkey plants.

6.03 These are positive signs of the development of technological capabilities in developing countries; however, major reliance for acquiring technology initially continues to mean the negotiation of a license with a foreign firm. Westphal, Rhee, and Pursell (1979) have reported on an extensive survey of sources of technology in Korea. They interviewed 112 exporting firms and reported that in process technology both foreign and domestic sources of know-how were mentioned. Local expertise was presumably acquired from a foreign source at an earlier time. The foreign sources were of several kinds, including licensing and technical assistance, experience gained overseas by a firm's own personnel, suppliers of equipment, and buyers of output. Data from many developing countries tend to indicate that foreign sources of technology are dominant and will continue to be so at least until some higher level of local capability is achieved, though adaptation by and diffusion among domestic firms may, in the long run be more important.

6.04 The costs of acquiring technology by license can be measured by the royalty rates and other charges. There are many variations of the formula for determining royalties but the most common is as a percentage of sales, whether gross or net. A range of 1% to 3% is fairly usual, but the rates vary among industries and countries. It is difficult to judge how
burdensome royalty rates are compared to other production costs, because details of license agreements and cost analyses are lacking. Since license agreements frequently have to be registered with the government, however, on an aggregate basis for the whole economy comparisons are sometimes made of royalty payments as a percentage of total exports. Table 1 below shows this ratio for selected countries.

Table 1. Ratio of Royalty Payments to Exports (%)

<table>
<thead>
<tr>
<th>Country</th>
<th>Year</th>
<th>Ratio</th>
</tr>
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<tbody>
<tr>
<td>Spain</td>
<td>1976</td>
<td>4.4</td>
</tr>
<tr>
<td>Korea</td>
<td>1976</td>
<td>0.4</td>
</tr>
<tr>
<td>Argentina</td>
<td>1974</td>
<td>2.6</td>
</tr>
<tr>
<td>Brazil</td>
<td>1976</td>
<td>2.7</td>
</tr>
<tr>
<td>Mexico</td>
<td>1971</td>
<td>11.1</td>
</tr>
<tr>
<td>India</td>
<td>1973</td>
<td>0.8</td>
</tr>
</tbody>
</table>

Sources: Spain: World Bank (1977); Korea: World Bank (1979b); Argentina, Brazil, Mexico, and India, UNIDO (1979).

The wide variation in the ratios is the result of several factors: the degree of export orientation, the level of industrial development, and the policy choices of the governments in encouraging or discouraging licensing arrangements. Korea and India have relied far less on licenses than has Mexico, for example. The royalties do not, of course, represent the full costs of the technologies acquired; the firm itself incurs costs in incorporating them in its operations and in learning how to utilize them.
Since the number of license agreements tends to rise as industry grows, there is a presumption that royalty costs, as usually agreed upon, are not a deterrent to expansion and do not impose a heavy financial penalty on the licensees.

6.05 Licensors often impose conditions on the use of the license; the most common clause attempts to limit the sales of the licensee to his domestic market and to constrain export sales. Other provisions that are sought include: control over the volume of output; tie-in sales of other inputs or equipment; price fixing; preferences for the foreign firm in the domestic market; discouragement of local RD&E and/or license-free access to improvements for the licensor; and controls over other areas of management responsibility. A UNIDO study (1979) contains a long checklist of provisions that may be contained in license agreements and another list of provisions that governments typically incorporate in regulations to prevent abuses. Argentina and Spain, for example, have extensive regulations on licenses; Korea is generally free of them, and Thailand has no regulations at all to protect domestic firms from exploitation.

6.06 Although in the past the bargaining power of foreign firms has probably exceeded that of the firms seeking licenses, the balance is being redressed as firms and governments of developing countries learn the art of negotiation and how to use the advantages they possess. Frank (1980) records the reaction of many foreign firms that the governments "know all the tricks." The situation is not that of a zero-sum game, however, in which what one side wins, the other loses. As labor and other costs rise in industrial countries, there are growing advantages in off-shore procurement and subcontracting arrangements in which both sides benefit.
Programs to assist firms in developing countries to raise the level of technological capabilities must take account of licensing opportunities and joint or subcontracted production as well as direct action to bring technical assistance and training to the firms. They are parts of a total "package" for technological development. But, as was emphasized in the preceding section, the efforts of domestic firms in adapting and mastering technologies is of prime importance, once a start has been made. For that reason, programs to support and improve these efforts deserve priority in industrial development.

VII. THE POLICY FRAMEWORK

7.01 Many industrial policies affect the technical choices that industry makes or stimulate (or impair) its ability and willingness to take the risks involved in technological change. Some policies have direct effects, but many have only indirect or marginal effects. This chapter focuses on the principal policies which have a direct impact on the choice and spread of technological change in industry.

7.02 The heart of an incentive or protection system normally includes the customs duties levied on imports and excise taxes levied on domestic production. Several other policy measures are often associated with them, including controls imposed through licensing and foreign investment laws, tax exemptions, and credit preferences. The primary objectives of this combination of policies are to control foreign trade and access to foreign exchange and to influence the allocation of resources in investment. Such policies affect technological development in developing countries in a number of ways.
7.03 First, rarely is there any systematic evaluation of the policy package to determine the costs and effectiveness of individual policies and to determine whether they complement or conflict with other policies in the package. Some policies may be costly (for example, in terms of government revenues foregone) and ineffective in accomplishing the intended objectives. Tax holidays may be ineffective, if they come during the early life of an enterprise, since the tax liability is contingent on the earning of income, and during its early history the enterprise may incur losses; only a long loss-carryover provision will alter that. There is a need for more explicit and systematic analyses of policy impacts, not only to determine their technological impacts but also to evaluate their effects on investment decisions.

7.04 Second, there is a fairly common pattern to protectionist policies in most developing countries. The highest levels of protection are given to light consumer goods (largely import substituting), with intermediate products being given moderate protection, and low or negative protection of value added being given to capital goods or engineering products. Since the last group is the primary carrier of technological change and, through linkages, affects the transmission of changes to other parts of industry and other sectors (such as agriculture, transport, and construction) the low levels of protection seriously impair the ability of these industries to grow. A pragmatic solution lies in narrowing the range of protection by decreasing protection in the high ranges and increasing it for capital goods, so as to move toward greater uniformity of treatment. Infant industry protection of capital goods is justified providing the infants grow into maturity; the protection should, therefore, be for a limited time.
Third, very high levels of protection and other policies that limit access to the domestic market undoubtedly dilute the incentives to innovate and to adopt new technologies. When competition from imports is largely removed, why should a domestic enterprise take the risks involved in research and development of new products and processes? It is safe to produce for the domestic market providing it is of reasonable size, to export when possible, and to be satisfied with reasonable unit profit margins in a high price regime. This usually also means that plants are operated at low capacity. Argentina has given evidence of many of these characteristics; in only a few industries (e.g. pharmaceuticals) is innovation proceeding at a relatively high level. This kind of experience is common in many large developing countries and suggests that to promote technological development, the trade policies: (i) should permit some competition between the domestic and foreign suppliers instead of banning or physically restricting imports; and (ii) the tariff protection should be for a limited time.

Finally, policies to stimulate technological development, particularly in the capital goods industries, are usually interventionist and discriminatory. This is not meant in any pejorative way, for there are strong arguments in favor of an interventionist approach (Choksi 1979; Datta Mitra 1979). In fact, without some intervention to stimulate and support development of capital goods, it is unlikely that they will develop at all in many countries, except in the very long run. There is nothing in the concept of dynamic comparative advantage that implies that countries cannot take steps to acquire the know-how and the economic basis for
efficient development of industries in which they are temporarily inefficient. The externalities or linkages existing in the capital goods industries constitute a powerful argument in favor of direct intervention. 7.07 The key issue in intervention is how much and of what kinds. There is no way to state precise rules. A policy framework that uses market forces and discipline, that is relatively open, has known advantages. But that is probably not sufficient. Because of the uncertainties, market risks, ignorance of technological information, inefficiencies in many activities, and incomplete infrastructure, it is necessary to have action programs that intervene to offset market imperfections. More analytical and detailed work is needed in order to choose combinations of policies and programs that are both effective in stimulating technological growth and yet take advantage of market forces. At present there are too many instances in which policy choices are based on conventional responses without sufficient detailed examination of their costs and effectiveness.

VIII. INSTITUTIONAL DEVELOPMENT

8.01 The success of any program to improve technological capabilities depends to a great extent on the institutions that are responsible for managing or coordinating the activities. As a consequence, in designing World Bank support of a national technological development effort, it is often necessary to devote as much time and effort to developing appropriate institutional arrangements and coordination as to the formulation of the substance of the program. In preparing the Mexican capital goods project,
for example, World Bank staff spent considerable time working with local authorities to ensure that the coordinating mechanism would promote maximum participation by the relevant financing and technical-assistance agencies.

8.02 There are a number of reasons for the importance that is attached to the institutional setting. First, there are usually multiple organizations in a country that have responsibility, in one way or another, for technical assistance to industry, though that responsibility may be ancillary to their main purposes. Research institutes both public and private; financial institutions, particularly development banks; large public corporations; universities; quasi-public and private industrial associations; chambers of commerce; and a variety of special purpose institutions may all have some assignments in technical assistance. It is this multiplicity of organizations and the consequent diffusion of responsibility over many of them that accounts for much of the weakness of technical assistance programs.

8.03 The difficulty of formulating and implementing a technological development program increases exponentially with the number of institutions involved. Each program will have to reflect the circumstances and institutional pattern of the particular country; there is no unique arrangement that can be mechanically applied in every case. While it may often be more effective to work with a single institution, there are instances in which the program will require the participation of many agencies. In the case of the Mexican Capital Goods Project cited in the preceding paragraph, a group of sophisticated agencies had already developed in financial and technical areas; the government program that the Bank project is supporting was designed to mobilize their efforts to focus
on a subsector that had not previously received the attention it required. On the other hand, the Korean Machinery Industries Project, which will bring technical assistance to small and medium-sized enterprises, has a single institution that exercises primary responsibility but cooperates with other institutions to undertake special tasks, such as on-the-job training or the channeling of funds.

8.04 Only the government has the power and the command over resources to act as midwife, promoter, and protector of a national program to improve technological capabilities, but the main beneficiaries are private sector enterprises, although public sector enterprises also often benefit. If the program is regarded as purely a government operation, the private sector may not participate fully and enthusiastically. There is typically some reluctance on the part of private enterprises to become intimately involved with a public program if it means detailed discussion of their own operations. The preferred institutional arrangement is one in which the private

9.02 Economists have argued that most countries tend to underinvest in RD&E activities. This is partly attributable to market imperfections but is primarily due to the fact that the knowledge created is often not appropriable—that is, no property rights can be created, so that the knowledge can be sold and yield a return on the investment made. Of course there are patents, which do confer such rights. Patents are of importance in a few industries, such as pharmaceuticals and chemicals; in others, although specific items may be patentable, much of the expertise that is acquired through RD&E is not patentable, and even when it is, there frequently are modifications to parts or processes that remove a copy from patent infringement. Patents have been the basis for the exercise of market power in some industries but are far less important in capital goods.
9.03 In developing countries there exists a bias against investment in RD&E, not only because of the issue of property rights but also because the purchase of foreign licenses is so easy. That is the reason that government intervention to support RD&E and to supply incentives to the private sector is essential. In this regard, however, it is important to note that RD&E covers a wide range of activities. Most developing countries need not be primarily concerned with the conduct of basic research nor with achieving breakthroughs in scientific knowledge. Instead, their concern should be the development of new products and processes, the adoption and improvement of existing technologies, and the engineering to achieve commercial success. It is the "D&E" end of the spectrum and not the "R" end, that directly affects economic growth. The distinction is important. Commentators on Japanese experience have noted that "most new technological developments in Japan have been in the areas of assembly processes and manufacturing technology, rather than inventions of new technologies. The Japanese do not confuse technological development with innovation. They speak of two entirely different fields of endeavor" (Gregory 1980). It is also significant for the design of an RD&E effort that for every dollar spent on research, at least ten dollars, and sometimes much more, is typically spent on development and engineering to bring a product to the market. These latter activities should take up the majority of the resources in an RD&E program in a developing country.

9.04 By comparison to the resources devoted to RD&E by industrial countries, the developing countries devote modest amounts, both absolutely and relatively. In 1973 the developing countries accounted for less than 3% of world total expenditures on research and development, and their ratio
of expenditures to GNP averaged about 0.35, whereas the ratio was 2.3 in industrial countries (UNIDO 1979). But they accounted for 12.6 percent of the world total of research scientists and engineers. It is not suggested that developing countries should necessarily allocate a greater percentage of their income to RD&E, but the pattern of allocation that greatly favor government institutions and non-profit organizations working on basic research rather than industrial firms, which tend to concentrate on product development and engineering, is disturbing, since the former group normally can not respond effectively to actual needs and opportunities in industry. The following comparisons of percentage allocation of RD&E expenditures in three countries illustrate the problem (World Bank 1979b):

<table>
<thead>
<tr>
<th>Percentage Allocation of RD&amp;E Expenditures</th>
</tr>
</thead>
<tbody>
<tr>
<td>Government and non-profit</td>
</tr>
<tr>
<td>institutes</td>
</tr>
<tr>
<td>Industry</td>
</tr>
<tr>
<td>Universities</td>
</tr>
<tr>
<td>Total</td>
</tr>
</tbody>
</table>

9.05 The data on other developing countries indicates a pattern similar to Korea's, with a concentration in government institutes and related organizations. This pattern reflects two conditions; first, the
government is the source of the majority of funds for RD&E and normal practice is to support government-related organizations rather than to contract with private industry. There is typically a lack of communication and an absence of community of interest between government and the private sector on the goals of RD&E. Second, industry does not have the incentives or the funds to undertake much work on its own. To undertake RD&E means establishing a separate unit in the firm and finding personnel to staff it. There is no tradition of regarding RD&E as a means to solve problems and to achieve a better market position. Also, in countries that have high protective tariffs on industrial goods, there is less incentive to spend on RD&E since the domestic market is safe from competition.

9.06 Occasionally, developing countries talk of establishing a target for RD&E spending in the form of a set percentage of GNP; 1% is sometimes set as a starting point. At best, these targets are incorporated in development plans but seldom are they accompanied by specific actions that will be taken to reach the target. This is probably just as well, since all such targets are arbitrary, and there is little point in establishing a target for spending if other conditions, in incentives and the institutional network, are not favorable for an expansion.

9.07 Even where an RD&E system is in effective operation it cannot be expected that the flow of commercially useful ideas will be continuous, at a high level, and adopted at a uniform rate. Failures do occur and outnumber the successes, but they can be tolerated because the payoff from one success will pay for many failures. Yet it takes time for the dissemination of a technological change and its adoption throughout a significant
part of an industry. Studies by Mansfield (1968, 1961) have indicated that delays in adoption of significant changes have frequently been substantial—up to 25 years in the U.S. for the adoption of transfer machines to interlock machine tools in automobile production. After the first adoption, however, imitative actions rapid diffusion to other firms.

Key Issues in RD&E Programs

9.08 There are four areas in which the RD&E programs in developing countries typically have problems. The difficulties are not overwhelming, but they are persistent, and a recognition of them is essential in designing a program or project that will succeed in contributing to the technological development of a country.

9.09 First, there is a predilection for basic research, which is considered to have more prestige than adapting technologies developed elsewhere and assisting industries to solve their immediate problems. Researchers tend to set themselves apart and define esoteric subjects, which unfortunately sometimes have the quality of proposals to rediscover the wheel. Links to industry are not established and there is little exchange of ideas; consequently, industry normally does not look to RD&E as a means to solve problems. This characteristic is not limited to industrial RD&E. A World Bank report (1979) on agricultural research makes the same point. This is not meant to denigrate the importance of basic research, but it is one step removed from solving the immediate problem.

9.10 Second, there is a tendency to regard an RD&E effort as equivalent to establishing special institutes and organizations. The institutional form of the program takes precedence over the substance of the work. "Bricks and mortar" and the creation of science cities absorb the energies
and the resources. This leads to a proliferation of institutes that are too weak to be effective. Indonesia has had dozens of institutes concerned with industrial RD&E, many with less than five professional staff, and this is not a unique case. A concentration of forces is not brought to bear on the problems.

9.11 Third, the programs are often undertaken without the assemblage of the necessary scientific and technical personnel. Such professional talents are usually in short supply in developing countries and some of them have experienced a "brain drain." But a reversal of the drain is possible if the monetary and non-monetary rewards of a specific project or program are sufficiently attractive. When Korea established the Korean Institute of Science and Technology, one of the first steps was to recruit Korean scholars who were studying or teaching at universities abroad or working for foreign firms. A core professional staff was assembled in this way. When the number of such scholars is not large enough to provide an adequate market, a core of indigenous staff members supplemented by special expatriate staff will fulfill the requirements for some time. To some extent this approach has been followed by the Metals Industry Development Center in Indonesia.

9.12 Finally, incentives to the private sector to engage in RD&E are often weak or non-existent. Incentives that are usually effective include tax concessions or preferential treatment for expenditures made; joint financing by government and industry; direct or matching grants; provision of infrastructure support on a common-use or special-use basis; rewards and prizes to individuals or firms; and supply of detailed technological information and intelligence. In many ways, a strengthening
of the incentives system is the easiest of the changes to accomplish, for
the others involve changes in institutions and behavioral patterns.
Unless the private sector becomes actively and substantially engaged in
RD&E, it is unlikely that any government can support a program that will be
effective.

**RD&E Projects:**

9.13 Governments in developing countries have not moved rapidly to
improve industrial RD&E programs nor to change incentives systems. This is
understandable in view of the many developmental efforts that have to be
undertaken. But as industrialization proceeds and a country builds a
substantial industrial sector, the necessity of taking some action to
improve its technological base becomes obvious. That has been an
observable pattern, but it has been limited to a modest number of
countries. So far as the experience and involvement in the World Bank are
concerned, specific projects have been, or are being, undertaken in several
countries, but it seems likely that the number will grow, particularly as
countries achieve a level of development at which they are almost ready to
graduate into the ranks of developed countries, for RD&E projects have the
greatest priority when industrial development is reasonably well advanced.

9.14 The first project for general support of industrial RD&E by the
World Bank was one in Spain, approved in 1977. It is the prototype of RD&E
projects and was intended as a model that could be replicated elsewhere.
Since that time several other projects have emerged. A recent one in Korea
creates a venture capital institution, the Korea Technology Development
Corporation, to support RD&E work that will lead to adoption of new
technologies; another in Korea supported RD&E in advanced electronic
equipment, through the Korea Institute of Electronic Technology. Others of a more specialized or limited type have been undertaken for Israel, Colombia, Turkey, Uruguay, and Portugal. In Spain, the project was the final World Bank operation before graduation.

9.15 The Spanish project is the only one that has been in operation long enough that its achievements can be judged overall, though several others, notably one in Israel, have demonstrated successes in individual cases. A newly created, semiautonomous corporation, the Center for the Development of Industrial Technology (CDTI), is the manager of the project in Spain. It accepts proposals for RD&E, evaluates them, both by its own staff and by means of special committees of experts, and can provide financial support, but not through grants. Its objective is to recoup funds to help carry out the program through royalties paid on successful efforts that lead to a commercial product. The initial funds were provided through the World Bank project and the Spanish budget. Its aim is to be financially self-sustaining after a period of perhaps eight years. The staff is small and largely drawn from private industry, as is the managing director.

9.16 During the formative years 1978-80 activities have grown slowly; 144 proposals have been received and about 50% have been approved, but not all have been completed. Yet some successes have been achieved, and the CDTI is receiving royalty payments from half a dozen or so. Most of the proposals are from medium and smaller sized firms. In 1980, about a quarter were from firms having fewer than 10 employees and more than 50% were from firms having fewer than 200 employees. The majority of proposals are for electrical and non-electrical machinery but food processing,
chemicals, conservation of energy, and other fields are represented. The response of industry to the program, in a country notable for the lack of RD&E activities in the past, and the successes achieved, though modest so far, are at least hopeful signs. It is still too early to tell whether the objective of a financially self-supporting system will finally be reached, but even should there be some short-fall, the economic benefits, both direct and indirect, should still be substantial.

X. SECTOR PROGRAMS

10.01 Another approach to technological development is assistance to a selected sector in the form of a "package" program of (a) technical assistance to improve the efficiency of current operations and to prepare plans for modernization of investment; (b) on-the-job training of first line-supervisors and management to raise skill levels in the factory; (c) supply of funds to make the necessary investments; and (d) policy reforms to remove constraints. The general objective is to alleviate or remove existing inefficiencies in the use of resources—that is, X-inefficiency—and to improve the competitive position of the firm. For reasons that are given below, the engineering industries deserve special attention, but similar assistance can be provided to other industrial subsectors. A successful program for the engineering industries can be expanded to the whole of industry.
The Case for the Engineering Industries

10.02 The engineering industries have certain characteristics, not shared by others, that make them logical choices to lead technological change in the economy. First of all, machinery and equipment has frequently been the largest category of imports, despite the petroleum price increases that have raised the cost of fuel and lubricant imports. Table 2 shows the percentage accounted for by these two categories compared to total merchandise imports, in selected regions.

Table 2. Percentage of Imports, 1977

<table>
<thead>
<tr>
<th>Region</th>
<th>Machinery and Equipment</th>
<th>Fuel and Lubricants</th>
</tr>
</thead>
<tbody>
<tr>
<td>All developing countries</td>
<td>31.5</td>
<td>17.5</td>
</tr>
<tr>
<td>Africa, below Sahara</td>
<td>42.9</td>
<td>5.8</td>
</tr>
<tr>
<td>East Asia and Pacific</td>
<td>27.6</td>
<td>17.3</td>
</tr>
<tr>
<td>South Asia</td>
<td>20.3</td>
<td>22.3</td>
</tr>
<tr>
<td>Latin America</td>
<td>30.2</td>
<td>28.8</td>
</tr>
</tbody>
</table>


Until about 1974 the figures were higher for machinery and equipment. By 1977, the relative percentages reversed for a few countries, such as India, Brazil, and Mexico, though they remain in the same order for Korea and Taiwan.

10.03 Machinery and equipment comprise a large and heterogeneous group of products. Many of them are standardized and relatively simple to produce; consequently, there are many products that a country can produce
and substitute efficiently for imports, plus developing export markets for parts and components. The domestic demand for machinery typically increases rapidly during development and is usually elastic with respect to both income and investment. The elasticity with respect to investment is normally in the range 2 or 3; for countries that have achieved a reasonable level of industrialization, such as Korea, the elasticity is somewhat greater than 1. Prakash and Robinson (1979) have shown that the engineering industries are typically the most rapidly growing of all industries, at levels of per capita income from $200 to $3,000 (at 1970 prices). At per capita incomes of $200, these industries normally account for 18 percent of manufacturing value added, but this rises to about 30 percent at per capita income of $775 and 37 percent at $3000. The elasticity of output with respect to GNP is about 1.6 for all manufacturing but about 2.3 for the engineering industries. The typical experience, based on a large sample of countries, is that engineering products grow rapidly during economic development, although many countries fail to equal the "average" or normal rates of growth.

10.04 A number of these products can be produced efficiently at small scale, which means that the investment required is modest and the firms are of medium or smaller size; however, there are many others for which economies of scale are extensive. They also tend to be flexible in the sense that the technology of production permits variations in the mix of factors. Of 181 products to which Forsyth, McBain, and Solomon (1980) assigned an index of technical rigidity, which reflects the ease or difficulty of varying factor proportions, virtually all the engineering products had indexes in the lowest three groups, indicating an ability to
adjust factor proportions toward labor if factor prices warrant it. Although they tend to be labor-intensive, these products are also skill-intensive, and the lack of sufficient skilled labor can, for a time, impair their ability to develop. The growth of skills, however, also means that increases in productivity and income will normally occur during the course of development.

10.5 Most important of all the factors characteristic of the engineering industries are the strong linkages that these industries have both backward to supplying industries and forward to users of machinery and equipment. There are "families" of products that support or complement one another. Technical changes in the engineering industries are passed on to both suppliers and customers. The ability to adapt products and designs to the needs of using industries and to instruct suppliers in the new designs of components and parts is a key ingredient of a technological development program. This ability is not at present characteristic of the firms in developing countries, but improvements in the capabilities of the engineering industries will almost immediately benefit the other sectors that are linked to them.

10.06 The existence of linkages is a powerful factor in spreading development but it also imposes a condition. Linkages are strong within the engineering industries themselves; for example, the processes of casting, forging, pressing and bending, heat treatment, machining, and assembly are often common to the production of a single item or piece of equipment. They lend themselves to specialization of production and are merged in the integration of production. Consequently, a development program to assist a core of interrelated product lines is necessary if the
full benefits are to be obtained; a piecemeal approach will not capture the externalities that can be generated. The parts and components must fit together, and the assembler of a final product must be able to depend on the reliability of the matching. Similarly, the market demands for the various products are mutually supportive. On both the demand and the supply sides, therefore, there are considerations that favor an integrated approach covering a core of products and firms. These considerations are compelling and affect the way that a program or project in support of the engineering industries is designed.

10.07 Specific projects covering the engineering industries have been approved for Korea, Mexico, and Tunisia and preliminary plans for Morocco, Indonesia, Thailand, Turkey, Pakistan and several other countries are underway. Because they differ from traditional World Bank industrial projects in several essential respects, it is desirable to describe the projects in some detail. The project for technological improvement of machinery producers in Korea is used here as the model (World Bank 1979b), although the other projects have similar frameworks. These projects have emerged from sector reports in which the strengths and weaknesses of the engineering industries in each country have been diagnosed, their prospects for development have been evaluated, and preliminary prescriptions for specific actions to improve the efficiency of the industry have been made.

10.08 Each project will be aimed at the technological restructuring of a selected group of enterprises so that they can compete effectively in both domestic and export markets. The projects thus involve technical assistance on the production floor to improve the use of current resources;
labor and management training on-the-job to increase productivity; a source of investment funds to rationalize and modernize existing plants and to assist new ventures; and advice on changes in incentive policies. In Korea the project was specifically designed to meet the most urgent needs of the machinery industries during the Korean Fifth Plan and to support a program that has been aimed at identifying and helping about 500 small or medium-sized companies that produce specialized parts, components, and sub-assemblies for machinery. These companies are suppliers to the large companies; without the effective performance of these component manufacturers the whole machinery sector may fail to meet the plan targets. Both existing enterprises and new ventures will be included, and the enterprises may be in the private or public sectors, or joint ventures.

10.09 Each project is planned as a "package" composed of the following elements:

(1) Technical assistance, largely in the form of production engineers, to work with the management of the enterprises to improve current operations and the uses of labor and equipment. Improvements are usually possible in many areas of work, such as the plant layout, operating practices, maintenance, and quality control. It is estimated on the basis of past analyses in several countries that productivity may be increased as much as 40% by this assistance. During this phase, plans will also be formulated for a rational-
and reduce costs, and an investment plan for expansion and/or modernization will be prepared. It is during this phase, also, that the question of factor use and choice of technologies will be addressed.

(2) Funds are available as complement to the package of technical assistance and training. It is expected that the demand for funds in the subsector would be much larger than the amount incorporated in the project. The project funds will serve as a magnet to attract additional funds through the market offered by the commercial banks.

(3) Training for both labor and management is the third element of the project. The plant visits by engineers have clearly indicated that machine operators and other production workers do not know how to operate efficiently the equipment they now have. On-the-job training can correct the deficiencies. The objective is not to make a machine operator able to perform on a variety of machines, but to increase his productivity in his present position. On-the-job training rather than vocational training in school is preferred, because it does not remove the man from the job. Similarly, it has been found that management training in such topics as production control and scheduling, marketing, costing systems, and inventory management is required, since many of the managers of medium-sized or smaller enterprises lack rounded experience in running a plant.
10.10 The projects were developed on the basis of detailed sector review which identified a preliminary list of products, including production of components and subassemblies, that appear to be in a relatively favorable position for initial emphasis. The criteria used for such selection include: (a) a strong market demand, both domestic and with export potential; (b) sharing of common inputs—that is, the backward linkage effect—which also strengthens the market for components, and complementarity in marketing—that is, the forward-linkage effect; (c) favorable technical conditions in the plants, so that existing cost disabilities can be readily overcome with some additional assistance; (d) product characteristics that do not impose too great a requirement for technical advances, such as standardized products for production of which the technology is well known; and (e) entrepreneurs who are prepared to make changes in their current practices.

10.11 There is a strong element of institution building involved in these projects, and it emerges most clearly in the discussion of the functions, powers, and responsibilities of the management of the project. The importance of creating and sustaining a vigorous project-management institution can hardly be overemphasized. In Korea, the project-management institution will include both the public and the private sectors in the internal management of the institution and in direct operations of the project.

10.12 Operations under the project start with negotiations between the project management and the individual enterprises that make application for the package of assistance. The project management will undertake to supply the technical assistance required for a reorganization of current
operations and for the preparation of a plan for rationalization and expansion. The plan will take into account the market for the products, the type and quantity of output, the technology that is applicable, the type of equipment and labor that is available and needed, and the investment and operating costs that will be involved. At this time also, the project management will arrange for in-plant, on-the-job training programs. When the changes in current operations are under way and the plan for rationalization and expansion has been agreed upon, the project management will certify the plan to a cooperating financial institution, which will review the financial position of the enterprise, and, if conditions are satisfactory, will make the loan to implement the plan. The project management will continue to work with the company during implementation but will gradually be phased out. With the package of technical assistance, training, and new investment, it is expected that the productivity and competitive position of the enterprises will be improved significantly.

10.13 The emphasis on the engineering industries is particularly appropriate to the middle-income countries, but the concept of the package program to improve technological capabilities is applicable to other industries and can be adapted to the needs of countries at different stages of development. The concept of a "core" of industries that have some inter-linkages has, for example, been adapted to the shoe industry, in which soles, eyelets, laces, and other components are suitable for smaller enterprises. Similarly, the emphasis on training, within a set of industrial skills, could benefit a group of enterprises. Even countries at
a low level of industrial development, like many in Africa and parts of Asia, could make use of the package program to capture the externalities. The products or industries in a program might include some parts of the engineering industries, since there are mechanical products that do not require high skills nor great amounts of capital.

XI. OTHER FORMS OF DEVELOPMENT ASSISTANCE

11.01 There are three additional areas in which further work and experimentation could improve technological development programs: (a) designing industrial research to understand the processes and consequences of technological change more fully so that there is better and more accurate guidance to operations; (b) strengthening the abilities of financial intermediaries to provide assistance to their clients, many of which are smaller firms; and (c) incorporating features in large industrial projects to yield additional benefits in technological improvements. Each of these contributes to the effectiveness of a total program.

Research Activities:

11.02 Throughout the paper, there are references to a number of problems to which there are inadequate answers or in which the conclusions of the work that has been done are ambiguous or insufficiently well-founded to provide guidance. Among these problems the following appear to be of particular importance:

(a) Further analysis of the contribution of technological change to economic growth in selected developing countries, at both the macro level and the level of the firm or industry would provide badly needed guidelines on the importance of this factor compared
to capital widening and deepening. As discussed earlier, the research results so far are on the U.S., Western Europe, and Japan. In order to decide on priorities in the lending program and the desirability of possibly shifting emphases to projects aimed at technological improvement, research on this topic would be useful.

(b) The scope for efficient factor substitution in a wider sampling of products than those already undertaken, which are of rather simple products that in the aggregate do not bulk large in the industrial sector, is especially germane to determination of project choices. Under what conditions and in what products do "induced innovations"—that is, changes caused by shifts in relative factor prices—occur?

(c) What are the instruments and the institutional arrangements by which technological improvements are or can be propagated and diffused throughout industry? Some research has been done on this topic or is being initiated.

(d) What are the functions and structure of the engineering industries at different stages of development? This work would expand on the work done by Prakash and Robinson, cited earlier.

(e) What are the returns and costs of various types of informal labor training?

(f) What kinds of advice do financial intermediaries supply to their clients and how effective are they? How can their effectiveness be improved?
11.03 This sampling of topics does not exhaust the list of those that are relevant both to a better understanding of technological change and to the design of projects. Due to the lack of any meaningful research so far on these issues, productivity is likely to be high in all the above topics.

Functions of Financial Intermediaries

11.04 Bank loans to development finance companies have often incorporated provisions for technical assistance to industrial clients. A loan to the Egyptian Development Industrial Bank (DIB) in 1977, for example, provided funds for technical assistance to smaller enterprises. Two organizations were involved, the Engineering and Industrial Design and Development Center (EIDDC) and the Productivity and Vocational Training Department (PVT) of the Ministry of Industry. The EIDDC created a technical extension service to visit firms, diagnose problems, and help on technical matters, such as the design of dies for molding plastic materials, as well as conducting training. The PVT organized courses for machine operators and management. A somewhat similar program in Turkey, through the SYK Bank, provided special funds to defray up to 80% of the cost of training. Other examples with varying characteristics can be found in loans to development finance companies in a number of countries.

11.05 This type of effort offers opportunities for expansion and refinement. A research project, undertaken through the OECD and with financial support from Canada's IRDC, has been exploring the function of financial institutions in technological development (Jequier 1981). Preliminary case studies have been made of the experience in eight
countries—Argentina, Brazil, Colombia, India, Ivory Coast, Malaysia, Mexico and Peru. These are largely descriptive, but some of the issues have been identified and a report is in preparation. Further detailed work appears to be justified and will be supported by IRDC for several countries.

11.06 The Bank undertook a preliminary review of technical-assistance components of development finance company loans to determine their extent and characteristics and to identify issues that have arisen during implementation. The issues included: difficulties in formulating the scope and content for technical assistance; measurement of results; the demands on monitoring the work; recruitment of skilled staff; and the means of ensuring the continuation of the programs. This preliminary evaluation was discussed with the regional divisions of the IDF to seek ways in which future loans can be better designed and made more effective in delivering technical assistance to client enterprises.

11.07 All these efforts are in early stages and may be supplemented or revised later. It is hoped that through these institutions technical assistance may provide a better complement to the provision of investment funds that are channeled through the financial sector.

**Assistance Through Large Industrial Projects**

11.08 Substantial Bank lending to industry is to large, complex industries such as fertilizer, pulp and paper, cement, and petrochemicals. In such projects there is frequently a component for engineering consulting assistance during the construction phase and for technical assistance and training for bringing the plant on stream. Continued assistance during early production is also provided at times. These are effective means to transfer know-how on complex production processes and the use of equipment...
and to train the managers and operators who will assume responsibility. There are at least two other areas in which additional work may further increase the local effectiveness of these large projects: (i) greater attention to alternative factor uses in parts of a plant's operation; and (ii) subcontracting.

11.09 It is unlikely that factor substitution and alternative technologies are feasible in the design and operation of some kinds of plants, such as those producing chemical products or fertilizers; factor use is largely dictated by the physical processes involved. Without impairing the integrity of the production line itself, however, it is possible that ancillary activities, including materials handling and support activities, may offer greater opportunities for factor substitution involving greater use of labor. In the identification and preliminary design of the project it is feasible to explore the principal alternatives explicitly and to adapt the final project configuration.

11.10 Subcontracting as a means of increasing local participation in a large project has received some attention in the past, primarily in occasional papers and informal documents. In preliminary project work the opportunities for increasing the subcontracting of parts, components, operating supplies, and maintenance services can be specifically explored. For example, it may be noted that the automotive industry in most developing countries has been required to increase the local content of the final product, and although the mechanical application of formulas linked to percentage increases in local content has often led to abuses and inefficiencies, the fact remains that the basic idea is sound, provided
that a demonstration of market efficiency is required of the supplier. It is appropriate to expect the large firm to find suppliers, to help them set up efficient production lines, and to monitor their quality controls. This is a means of transferring the technological capabilities to a wide variety of firms. This type of approach can readily be incorporated in industrial lending.

XII. A ROLE FOR THE WORLD BANK

12.01 The three prior chapters have described types of projects and activities that the Bank has undertaken in the recent past to support technological development. A listing of the projects indicates the heterogeneity that is a chief characteristic; the projects include:
(a) "package" programs of technical assistance, training, provision of funds earmarked for technical improvements, and associated policy changes;
(b) projects administered through development finance companies and aimed at providing assistance to clients who are chiefly smaller enterprises;
(c) support for RD&E in specific industries (such as electronics) or more broadly based (as in Spain); (d) venture capital projects; and (e) professional engineering and technical assistance in conjunction with large industrial projects. In spite of this variation, actual experience is limited to a relatively few countries although in an additional number of countries project identification is underway. The first project with the primary objective of improving technological capabilities was approved only five years ago; the Bank is still learning the most effective means to improve capabilities and the institutional arrangements for implementation.
12.02 A future role for the Bank in this important element of the development process will require finding practical solutions to a number of issues. First, although capital widening and deepening through normal project lending will remain a key part of Bank operations, the fact is that industrial growth and development is retarded increasingly by technological incapacity—the inability to choose and use modern equipment and facilities in an efficient fashion. This is particularly true in the middle income countries that have a reasonably large industrial sector, but this also applies, to some degree, to countries at earlier stages of development. Greater attention is needed to diagnose the sources of industrial retardation and to design projects and programs that will improve technological capabilities together with increasing capital investment in industry.

12.03 Second, projects specifically aimed at technology development so far have evolved in a pragmatic and ad hoc way. Since conditions vary widely among countries, this will probably always be somewhat true, but a greater effort to develop a systematic approach, to learn from the projects what seems to work successfully and what does not, to replicate and adapt successful ventures, are required. As noted earlier, this may involve further research on the importance of technological changes as a source of growth in developing countries. It probably also requires a sharpening of the issues that are covered by sector missions and some adaptations in the work of project preparation missions.

12.04 Third, discussions on industrial policies should place greater emphasis on the impact of various policies on technological development. At the same time, the policy advice given to accomplish the technological
development objectives has to be specific, in depth, and operationally meaningful. For example, studies of the general impact of the incentive system (i.e., tariffs, taxes, etc.) in a country should establish the links between the studies' findings and the specific actions or standards in a revised incentive system. At present these linkages sometimes appear rather weak.

12.05 Fourth, there is a great deal more to be learned about the institutional and other means for transferring technology and for applying it effectively. Further research has been mentioned previously but learning-by-doing is obviously important.

12.06 Finally, projects for technological improvement may place greater demands on Bank staff than do conventional projects, because the former are intimately involved in changing behavioral patterns and decisions that are internal to a large number of firms.

12.07 The role of the Bank in supporting technological change in industry probably will expand through normal evolution even if no conscious new efforts are made to focus on the issues. But opportunities now exist that would make such efforts highly productive. Industrial sector work and the work started so far have established the desirability of undertaking projects to improve technological capability, the feasibility of doing so, and the interest of governments to obtaining assistance to undertake this development effort. Although the total program is still modest, it holds the promise of becoming an important direction for industrial policy dialogue and lending operations in the future.


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