Every year developing countries must create more than 50 million new jobs merely to prevent their levels of unemployment and underemployment from worsening. Physical limitations and already high rates of underemployment restrict the potential for job creation in agriculture. The service sector is also overcrowded, and productive employment can be expected to grow only slowly. This leaves manufacturing as the single potential source for most of the new jobs that must be generated. Given the present cost of creating a manufacturing job, however, this sector will be able to absorb only a fraction of the new entrants into the labor force at present investment levels.

Faced with such alarming prospects, developing countries have been searching for policies that will lead to significant increases in the creation of employment. Lowering the investment cost per job created is one of the most obvious ways to achieve that aim. It seems reasonable that given the developing countries' relative abundance of labor and scarcity of capital, they would use technologies that require little capital and large amounts of labor for the production of a given good.¹

This idea, however, has provoked one of the greatest controversies in the field of economic development. Although the subject of much research and argumentation, the basic questions concerning the potential for substituting labor for capital in manufacturing remain unanswered. Little consensus has been reached on the existence of labor-intensive technologies or the potential benefits to be drawn from their application. Further disputes exist about the extent to which these technologies are already in use in developing countries, the reasons why they may or may not be adopted by manufacturing facilities, and the means by which their wider adoption could be promoted.
This study investigates the following issues:

- Are alternative technologies available to perform a specific manufacturing operation? Do these alternative technologies use the factors of production in significantly different proportions?
- How do the technologies adopted by manufacturing firms in developing countries compare with the alternatives available in terms of quantity of the different factors of production required?
- What are the considerations that lead a firm to adopt a specific technology rather than alternatives? And how do these considerations enter the decision process?

These issues are addressed by means of a comprehensive survey of the offerings of pulp and paper and textile equipment suppliers and a detailed analysis of the technology choices made for production facilities in developing countries. The relevance of this work should not be limited to these two industries, however. The system of analysis of technology choices developed here can be applied to other industries to provide answers to the same questions. This methodology can also be used by firms to evaluate alternative technologies and by governments to assess the impact of proposed policies on technology choice. Furthermore from the findings in this inquiry, preliminary conclusions can be reached regarding the form and characteristics of alternative technologies available in different types of industries, the selection behavior of specific types of firms, and the impact on technology choice of specific government policies.

The Controversy about Technology Choice

Economists and policy makers not only accept the questions addressed here as relevant but also as crucial to the issue of technology choice. But there the consensus ends, however, and there has been little agreement about the answers to these questions. A rapid review of the main schools of thought will show the scope of the controversy.

The Existence of a Range of Alternative Technologies

This is the premise on which the notion of technology choice rests. For technology choice to be a relevant issue, there needs to be a range of alternative technologies available to produce a specific good at a given scale of production. Furthermore these technologies have to make
The Choice-of-Technology Issue

use of the factors of production in proportions different enough for the choice among them to have a significant impact on the demand for these factors.

The controversy about technology choice also begins at this juncture. So little information has been collected about the availability and characteristics of alternative technologies for the production of a given good that the most contradictory positions still coexist on this issue. Neoclassical economic theory assumes the existence of an infinite number of alternative technologies available for the production of any good at any scale. It also assumes that these alternative technologies create a continuum along which it is possible to substitute one factor of production for another. Others argue that there are no alternative technologies and consequently that there is no choice for a rational decision maker. According to them one technology—generally the most modern one—uses both less labor and less capital than the other and, being altogether more efficient, should always be preferred.

Characteristics of the Technologies Adopted

If there is a range of alternative technologies for the production of a given good at a specific scale of manufacturing, one should then wonder what the characteristics of the technologies chosen are as compared to the characteristics of the alternatives. Since the emphasis in the technology choice issue is on the quantity of the different factors of production that may be put to use by alternative technologies, this should be the criterion used to compare the technology that is chosen against its alternatives.

Neoclassical economic theory posits that the play of market forces should result in a pricing of the factors of production such that the technology using these factors of production in a proportion closest to their relative availability in the economy should yield the lowest cost of production. Therefore a rational decision maker, whose aim is the minimization of production costs, should always choose this technology. If chosen by all production units in the country, these technologies should result in the full use of the factors of production. In other words the adoption of such technologies should lead, among other things, to full employment.

Although from a logical point of view, the neoclassical theory of technology choice is unassailable, a cursory review of the employment situation in developing countries indicates the theory’s incapacity to
explain actual conditions in these countries. Most developing countries are plagued by constant unemployment and underemployment, a situation that cannot be reconciled with neoclassical theory. Several arguments have been advanced to explain this discrepancy, but the accumulated empirical evidence has not allowed a testing of the different explanations offered.

Three main lines of explanation exist for the failure of technology choice to lead to full employment of the factors of production beside the above-mentioned argument of technological fixity (the absence of alternatives). One concentrates on the link between factor availability and factor prices. Market imperfections and government intervention, its proponents contend, result in factor prices that do not correspond to the relative availability of these factors. Private decision makers may well choose the cost-minimizing technology, but since this is based on prices that do not reflect the availability of the factors, full employment of the factors of production will not result. Therefore the factor price determination mechanisms, not the technology choice procedures, are at fault.

Another explanation stresses the limitations of a two-factor model of technology choice. It notes that the labor factor of production includes unskilled, semiskilled, skilled, supervisory, and managerial employees, while the capital factor of production is made up of both local currency and foreign exchange. Furthermore alternative technologies might also differ in their use of some other inputs such as power, raw materials, and chemicals. Under such circumstances it is highly unlikely that a technology can be found that will use all of the factors of production and inputs in proportions equal to their relative availability. The technologies chosen, although cost minimizing among the sets of available alternatives, might therefore still lead to the underemployment of some factors of production.

The third explanation questions the mechanism that the neoclassical theorists assume to be the one that leads to technology choices. Production cost minimization, the countertheorists argue, is not the ultimate objective of the decision maker in choosing a technology. This is because imperfect markets and product differentiation allow firms to escape price competition. Since they are not under pressure to minimize their firm's cost of production, these managers will try to satisfy other objectives. In that event, for example, minimization of the risk associated with the use of untried alternatives and reinforcement of the stability of an oligopoly will become decisive factors in the choice of technology.
Influence of Industry and Firm-Specific Characteristics

Although the empirical evidence so far has not allowed for a testing of the alternative explanations as to why technology choice has not led to full employment, it has pointed to significant differences in the characteristics of the technologies chosen among industries and—within an industry—between firms. Here it is commonly acknowledged that industry characteristics influence the profile of the technologies chosen. Difficulties encountered by previous studies in comparing technology choices in different industries, however, have resulted in little agreement over identifying these characteristics. Chemical industries are generally described as more capital intensive than mechanical industries. Yet it has not been shown whether this was due to differences in the spectrum of available alternatives or in the pattern of technology choice.

Important differences of behavior have also been found among firms in the same industry. Such differences include national origin (foreign versus local), ownership (public versus private), management profile, and strategy. Although these patterns have been better researched than the differences between industries, the contradictory findings made for them lead to the questioning of some of the variables that have been considered relevant and of the rationale behind them. For example, since foreign firms have been found alternatively to adopt more capital-intensive and more labor-intensive technologies, the fact that they are foreign might not be the best explanatory variable of their technology choices.

Previous Studies

Four basic weaknesses can be found in most of the studies of technology choice in developing countries that have been conducted so far. To a large extent, these shortcomings in methodology explain the often contradictory nature of their findings and the lack of acceptance of these findings as definitive.

At the outset most studies fail to identify and separate the main reasons that should lead to the choice of different technologies in different environments. They do not recognize differences in the scale of production, in the characteristics of the inputs or the output, and in factor prices. Secondly, practically all of these studies lack a frame of reference against which to evaluate the technology choice made by specific firms. This is because they do not first establish the range of
The Choice of Technology Issue

alternatives available to the decision maker. Thirdly, the quantitative tool used to compare technologies and evaluate their suitability to a specific environment takes only two very aggregated factors—capital and labor—into consideration. Finally the tools used to assess technology choices do not allow for the identification and isolation of country-specific, industry-specific, and firm-specific factors that influence technology choice.

Differences in Factor Costs: Defining the Observational Units

In most other studies little emphasis is placed on isolating the impact of differences in scale of production, in input or output characteristics, and in the factor cost structure that firms must consider in choosing a technology. Since the focus of these studies is the adaptation of technology to factor prices, their authors tend to attribute all of the differences in production technologies encountered to differences in factor prices. But this tends to blur the results and make their interpretation difficult. It may also introduce a systematic bias into their results since production facilities in developing countries are generally of a smaller size than in developed ones.

To a large extent this weakness can be traced to the definition and selection of the observation units on which most of these studies are based. The choice of technology observation unit most often used is an entire, contiguous production facility. The technologies used by these entire plants are compared, and alternative technology choices must then be defined at the plant level. In order to isolate differences in technology caused by differences in the cost of the factors of production, only plants of comparable scale of production, input, and output characteristics and age of equipment should be compared.

Such requirements are extremely difficult, if not impossible, to fulfill because: there is a lack of comparability between whole factory processes due to differences in the input and/or output mix; in any given industry and developing country, there are usually very few plants, let alone plants of identical size; and devising alternative technologies for an entire plant poses problems of line balancing.

In most cases it is impossible to determine the age of a plant since the equipment in it has been installed at different times. For each expansion of capacity or renovation, equipment is brought in to add to or replace older equipment. This causes a variation in age of equipment even in the same processing step.
Even if such a plant is entirely built and equipped on the same date, it normally is the product of a number of discrete investment decisions. The summation of all of these into some aggregate measure of technology appropriateness probably results in overlooking individual choices whose impact might have cancelled each other out and does not provide much insight into the process of analysis and choice followed by the decision makers.

The inquiry presented in this book showed that these investment decisions tend to coincide with processing steps. It is logical, therefore, to examine each processing step of a facility separately and to take note of the technology decision made for that processing step. Therefore such investment decision units instead of complete manufacturing processes were chosen as the basic observational unit of this study.

Although industry practice was followed as much as possible in defining investment decisions, an investment decision may be described as a group of machines purchased at the same time that are performing the same processing step in the overall production sequence. Thus if all machines used in a processing step were installed at the same time, they will constitute an investment decision. If because of equipment replacement or expansion of capacity, machines performing a processing step were purchased at different periods, each group of machines purchased at the same time will be considered as an investment decision.

A final problem in defining a unit of observation for this study is that in most production sequences, a processing step usually is performed not by a set of identical machines but by identical clusters of machines. In each such cluster there is normally a main piece of equipment and a set of auxiliary pieces of equipment, such as driving engines, pumps, and control devices. The choice, then, is either to collect information and identify alternatives for each piece of equipment of the cluster or to aggregate these pieces of equipment.

It is impractical to try to collect information on each of these pieces of equipment; for example, a pulp and paper mill is composed of some 10,000 such pieces of equipment, among which there are approximately 6,000 pumps and 3,000 engines to drive the processing equipment, while there are only a hundred or so pieces of equipment doing the actual processing. Also, given the broad practice of the industry in evaluating alternatives, it was decided to aggregate the auxiliary equipment with the main processing machine into an observational unit. Investment costs and input requirements, including labor, collected for this study will therefore refer to these clusters. Such a practice should
lead to more reliable conclusions than considering only the main processing machine without taking the auxiliary equipment into account. This should allow for differences in the cost of the auxiliary equipment required by alternative technologies to be taken into account in making a choice between these alternatives.

To conclude, the use of observational units so defined has several advantages over the comparison of the technology of whole plants.

1. It corresponds more closely to the pattern of decision making in the firm.
2. It results in observational units that are more easily comparable since differences in the characteristics of inputs and/or output mix result in the addition, deletion, or increased emphasis on certain processing steps rather than important changes in the function of these steps.
3. It allows for a more precise definition of comparable scales of production for the purpose of technology choice in a given processing step, therefore making it possible to decide if two observational units are comparable regardless of the size of the plants in which they operate.
4. It makes it possible to give a precise age to a unit and to compare decisions that were made at roughly the same time, from among the same range of alternatives.

Creating a Frame of Reference: Defining the Alternatives

All previous studies have been based on comparisons of the technology used in a specific plant against the factor availability in the country in which this plant is located or on comparisons of the technologies adopted in different plants producing roughly similar goods and located in similar environments.

Several limitations exist when comparing a chosen technology to factor availability since the assumption is made that for the production of a given good, a technology combining the factors of production in a proportion equal to their availability must always exist. The existence of such a technology is in fact one of the basic issues in the choice of a technology and cannot be pushed aside by means of an assumption. When the technologies used by different plants are compared, the assumption is made that if enough plants are investigated, all of the available technologies will be used by at least one plant and therefore will be taken into consideration. This assumption runs to the core of
the question to be answered: if all firms use the same technology, should the conclusion be that the choice-of-technology issue is a false one since there are no alternatives? Or is it a crucial one since alternatives are not chosen?

An alternative study design is to compare the technology choices made by firms to a systematic inventory of all of the alternatives available. Only by defining all of the alternative technologies available for the production of a given good can the optimum choice in a given environment be identified and the choices made by specific firms compared to this optimum. Such a procedure will provide insight into the reasons for adapting or not adapting to factor prices by application of such a procedure and the real costs, both financial and economic, of choices that depart from the optimum can be ascertained in this way.

In this inquiry the technology choices made by the firms studied will be evaluated by matching them up against an independently established spectrum of alternatives available at the time of the choice. In each of the two industries studied a systematic effort was made to identify the characteristics of all the models offered by equipment suppliers for each of the processing steps for which technology choices were analyzed. These models were then grouped into clusters according to their technical and operating characteristics. The clusters, or alternative technologies thus defined, constitute the whole range of alternatives from which the decision maker could choose. This technological range is not unlimited and continuous as assumed by neoclassical economic theory, but neither is it restricted to technologies already chosen by the firms studied.

Measuring Technology Appropriateness: Developing a Quantitative Yardstick

Capital-labor Ratios
Although there have been notable exceptions, most other studies of technology choice are based on the use of various ratios of capital to labor, capital to output, or labor to output for the purpose of comparing technologies and examining the technologies' appropriateness to a specific environment.  

The use of such ratios in the context of technology choice poses several important problems. These ratios are industry dependent and therefore do not allow for interindustry comparisons unless one assumes that different degrees of capital intensity between industries are only
the result of different patterns of technology choice. They are likely to vary according to the size of production facilities in any industry in which there are economies of scale. They are dependent upon the level of capacity utilization attained by a firm. As a result, if care is not exercised in selecting observational units and in interpreting results, the analyst might obtain different values for these ratios among firms that use the same technology or have the same pattern of technology choice. In other situations similar values might actually conceal differences in technology or behavior.

These ratios, even in their most sophisticated form, also limit the study to the consideration of only two factors of production: labor and capital. They exclude from the comparisons other factors in the choice of a production technology such as raw material usage, power consumption, spare parts requirements, and processing chemicals usage. Furthermore they assume the homogeneity of the labor and capital factors of production. The labor factor of production, however, is an aggregation of supervisory, skilled, semiskilled, and unskilled workers whose cost and availability often vary widely within a developing country. In the same way capital may be required either in the form of local currency or of foreign exchange whose relative availability might also vary. Finally it is impossible to evaluate the costs or benefits that may accrue to a country or a firm by choosing one technology rather than another from an analysis of these ratios.

For these reasons capital-labor ratios will not be used in this study to characterize alternative technologies or to evaluate technology choices. Instead alternative technologies will be defined by their production input structure. The relative suitability of these alternatives to a specific environment will then be evaluated in terms of the production costs that would result from applying the prevailing input and factor prices to the technologies’ production input structures.

**Production Input Structures**

The production input structure of a technology may be defined as the quantity in physical terms of each input (capital in local currency and in foreign exchange, different skills of labor, raw materials, spare parts, utilities, and so forth) needed for the production of a given quantity of output through the use of that technology. Each technology can thus be identified by its production input structure and each environment by the cost of these different inputs. At a given scale of production, technology adaptation then becomes a matter of matching the input
structure of a technology with the factor price structure of a country in order to minimize production cost.

The use of production input structures to characterize differing technologies has an advantage over capital-labor ratios in that it does not limit the analysis to the consideration of only two factors of production. Differences in the rate of consumption of power, spare parts, raw materials, and other factors between two alternative technologies can be taken into account, thus resulting in a more realistic representation of the choices available to a country or a firm. They also allow for the consideration of differences between the skills required to operate alternative technologies. In the same manner they enable an investigation of differences in the cost of local currency and foreign exchange funds. This becomes important, for example, when equipment of one technology is available locally but equipment of another must be imported.

The production input structures of all alternative technologies were derived for each technology choice decision examined. Applying the factor cost structure of a country to the production input structure of a technology yielded the cost of production using this technology in that environment. If the market price (price to the firm) of the factors of production is used in this computation, the resulting production cost should be the actual cost to the manufacturer. If the economic price (shadow price) of the factors of production is used, the production cost should then be the economic cost to the country.

Based on such a representation of the spectrum of available alternative technologies this system of computation can generate quantitative estimates that answer some fundamental questions about technology choice. For example, it is possible to evaluate the impact of factor price distortions on technology choice and its economic cost. Quantitative estimates can also be made of the potential for adaptation when going from one country to another and the cost and benefits accruing to a firm and to its host country when it chooses one technology over another.

Comparing Technology Choices: Developing an Adaptation Index

To identify the considerations that influence technology choice, the choices made by firms with different characteristics need to be compared. Studies that employ capital-labor ratios to define technologies do not allow for meaningful interindustry comparisons. In fact even in the
same industry they may yield unreliable results if such ratios are used to compare technology choices made in different production steps.

For example, a firm in industry A invested $10,000 in equipment per job created. At the same time a firm in industry B invested $30,000 per job created. Does that mean that the firm in industry A was more prone to choose labor-intensive technologies than the firm in industry B? If the spectrum of alternative technologies had been the same in industries A and B, the answer would be yes. But the answer would be different if the available alternative technologies in industry A were to range from $5,000 to $12,000 per job created, while in industry B, they ranged from $30,000 to $50,000. In that eventuality, the firm in industry B should be considered more prone to adopt labor-intensive alternatives than the firm in industry A. A similar example could be furnished to point to the dangers of using capital-labor ratios to compare the choices of technology made in different processing steps of the same industry.

Clearly an index of technology choice is needed that would be independent of the range of alternatives available to perform a specific operation. This would inform an investigator where the technology chosen is located in the range of alternatives. Comparing the values of this index in different processing steps, in firms of different characteristics, in different countries, and in different industries would then permit the identification of the factors influencing technology choice.

An index measuring the propensity of firms to adapt their technology choice to the cost of the factors of production they encounter was developed for this study. This index indicates the position of the technology chosen relative to the technology that would minimize production cost in that environment and the technology that minimizes production cost in the United States. (The technology that minimizes production cost in the United States was used as a reference point since it was considered to be representative of the technology choice made in a capital-rich, labor-poor economy.) This index is based on the production cost that each of these three technologies would have yielded in the economic context in which the plant were to be situated.

**Methodology of the Study**

In this study the technology choices made by twenty-eight firms in developing countries were investigated, using the parameters described. The analysis sequence outlined below was followed for each technology
choice. This inquiry is based on a previously established list of alternative technologies available to perform the operation considered, as well as a definition of each of these alternatives in terms of its input structure. A notational description of this analysis sequence is shown in table 1.1.

Measurement of the Potential for Adaptation

The potential for adaptation is defined as the production cost savings that can be realized by using the technology optimum for the factor costs the plant must pay, as compared with the technology optimum for United States factor prices. In the quantitative analysis of these data, the following neoclassical definition of optimality has been adopted: In a given environment the optimal technology is defined as the one yielding the lowest production cost. The assumption here is that the decision maker's only objective in making a technology choice is to minimize production costs. Of course, other considerations might influence the technology choice decision. One of the aims of this study is to identify them.

The potential for adaptation in each technology choice studied is computed in the following manner:

1. The cost of the factors of production to the firm is applied to the production input structure of each of the alternative technologies. From this is computed the production cost that would result from the use of each of these alternatives.

2. The technology giving the lowest production cost is selected as the optimum technology for that firm.

3. The technology yielding the lowest production cost at U.S. factor prices is selected as the U.S. technology.

4. The production cost that would be incurred by the firm if it were to choose the U.S. technology is selected to be the production cost without any technology adaptation.

5. The potential for adaptation is equal to the difference between the production cost that would prevail if this firm were to use the U.S. technology and the production cost if it were to adopt the optimum technology for its factor costs.

This potential for adaptation is a measure of the production cost savings that the firm would realize if it employed the technology most
### Table 1.1
Analysis of a Technology Choice Decision

<table>
<thead>
<tr>
<th>Structure of Production Input</th>
<th>Inputs at Market Prices LDC A</th>
<th>Inputs at Shadow Prices LDC A</th>
</tr>
</thead>
<tbody>
<tr>
<td>U.S. Technology</td>
<td>$X_{us} =$ Private production cost without adaptation</td>
<td>$Y_{us} =$ Social production cost without adaptation</td>
</tr>
<tr>
<td>Technology used in LDC A</td>
<td>$X_{1} =$ Private production cost with present adaptation</td>
<td>$Y_{1} =$ Social production cost with present adaptation</td>
</tr>
<tr>
<td>Alternative Tech$_1$</td>
<td>$X_{2} =$ Private production cost using Alt. Tech$_1$</td>
<td>$Y_{2} =$ Social production cost using Alt. Tech$_1$</td>
</tr>
<tr>
<td>Alternative Tech$_2$</td>
<td>$X_{3} =$ Private production cost using Alt. Tech$_2$</td>
<td>$Y_{3} =$ Social production cost using Alt. Tech$_2$</td>
</tr>
<tr>
<td>Alternative Tech$_3$</td>
<td></td>
<td></td>
</tr>
</tbody>
</table>

**Step 1**
The technology having the smallest $X$, $X_i$, is the optimum technology from the private point of view (market prices) in LDC A.
The technology having the smallest $Y$, $Y_i$, is the optimum technology from the social point of view (shadow prices) in LDC A.

$X_{us} - X_i =$ Potential for adaptation at market prices in LDC A.

$Y_{us} - Y_i =$ Potential for adaptation at shadow prices in LDC A.

**Step 2**
$Y_i - Y_1 =$ Economic cost of factor cost distortions in LDC A.

**Step 3**
$X_{us} - X_{A} =$ Private savings realized by present level of adaptation in LDC A.

$Y_{us} - Y_{A} =$ Economic value of present level of adaptation in LDC A.

**Step 4**
$X_{us} - X_i =$ Propensity to adapt exhibited in technology choice decision studied.

$X_{us} - X_{1} = f$ (explanatory variables)
closely suited to its cost of the factors of production instead of the technology best suited to U.S. conditions.

These computations will first be made using the cost to the firm, or market price, of the factors of production. When the market price of the factors is used, the optimum obtained is the one for the private decision maker. The potential for adaptation represents the savings this decision maker would then reap from full adaptation. These computations should then be repeated using the economic (or shadow) price of the factors. The economic cost of the factors leads to an optimum, which is based on the availability of these factors rather than on their possibly distorted market prices. The optimum, then, is the one for the country rather than for the private decision maker. The potential for adaptation becomes the measure of the economic savings, rather than monetary savings, to be made from full adaptation.

Measurement of the Economic Cost of Factor Price Distortions

Factor price distortions exist when the market prices of the factors of production do not fully reflect the relative availability of these factors and therefore their economic value. Such factor price distortions should cause the optimum technology—as determined on the basis of market costs—to be different from the optimum technology determined on the basis of economic costs. The private decision maker will then be pushed toward a choice of technology that may be cost minimizing from his or her point of view but might not be so from the country's point of view. Even if this manager were to behave according to the precepts of neoclassical economic theory and choose what he or she perceives to be the cost-minimizing technology, the host country might still suffer economic costs resulting from these distortions.

The additional economic costs resulting from factor price distortions can be quantified using the framework developed to measure the potential for adaptation. They are equal to the difference between the economic cost of production of the market optimum technology and the economic cost of production of the social optimum technology.

Evaluation of the Amount of Technology Adaptation that Took Place

Each of the technology choice decisions examined resulted in the adoption of one of the alternatives. The next step is to evaluate this choice
The degree to which this measure of adaptation depends upon the range of alternatives available and the general level of production costs confines its usefulness to comparisons of technology choices within the same processing step. To make possible interstep and interindustry comparisons, a normalized measure of adaptation needs to be developed.

A measure of the amount of adaptation that took place is derived in the following way:

1. The cost of the factors to the firm, when applied to the production input structure of the technology the firm actually chose, gives the actual production cost of the firm, given its current level of technology adaptation.

2. The value of the amount of adaptation that took place is the difference between this production cost and the production cost that would result from the use of the U.S. technology in that facility.

The computations in this step are first done using the market price of the factors of production and then using the economic costs of these factors. The use of the market prices of the factors of production yields a measure of the amount of adaptation done, which is equal to the financial savings the firm realized by choosing the technology it selected rather than the U.S. technology. The use of the economic costs of the factors leads to an evaluation of the social cost of production of the chosen technology to the host country. The measure of the adaptation that has occurred then becomes the economic savings realized by the firm’s choosing this technology rather than the U.S. technology.

Derivation of the Propensity to Adapt

The degree to which this measure of adaptation depends upon the range of alternatives available and the general level of production costs confines its usefulness to comparisons of technology choices within the same processing step. To make possible interstep and interindustry comparisons, a normalized measure of adaptation needs to be developed.

The propensity to adapt referred to here is defined as the ratio of the value, at market prices of the factors, of the adaptation done by a firm to the value (also at market prices of the factors) of the potential for adaptation. This measure of the propensity to adapt of a firm identifies where its technology choice is positioned between the U.S. technology and the optimum technology at market prices of the factors of production. Therefore it is independent of the range of alternative technologies available and of the level of production costs.
Values taken by the propensity to adapt for different technology choices can then be explained by country-related, industry/product-related, and firm-related variables. Such an analysis should lead to the identification and appraisal of the considerations that influenced technology choice.

The Firms Studied

The firms were chosen so as to allow enough variation in those variables that are considered to influence a choice-of-technology decision most heavily. The determinants of technology choice identified in previous studies can be classified into industry-related, country-related, and company-related variables.

Among the industry-related variables the number of alternative technologies available to perform a given operation, as well as the type and scope of the trade-off between factors of production that characterize these alternatives, could have an important bearing on the questions to be answered. For example, although few studies of the choice of technology in chemical processes exist in the literature, it appears that the type of transformation process (mechanical versus chemical) is a determinant of the propensity of a firm to adapt its technology. Some other industry-related variables that should be examined are the level of competition (also country related) and the cost of information.

The main country-related variable in this inquiry is the cost of the factors of production. The economic costs of the factors of production are clearly country related because they depend only upon the demand and supply of these factors within a country. Some of the market prices of factors are also country related, such as the exchange rate and the cost of power if it is produced outside the firm. Others, such as the cost of capital and the efficiency of the work force, are company-related variables. Still others, such as the cost of the different types of labor, are both country and company related since the company can decide to deviate from the country norm. Policy-related variables, such as tax rates and protection granted, and items such as the local portion of each technology’s equipment cost are also country-related variables.

The characteristics of the firm are company-related variables. They include the ownership of the company, its decision process to choose a technology, its market positioning, and the size of its production facilities.
Based on this analysis of what are considered to be relevant variables, the following sample was selected.

Industries

Two industries were selected because they were thought to have widely different characteristics and would therefore yield interesting comparisons:

- Textile: The spinning and weaving of short staple fibers (cotton or artificial or mixes of the two) into gray cloth.
- Pulp and paper: The sulfate process pulping of wood, with or without bleaching and chemical recuperation, and papermaking.

In its spinning and weaving steps the textile industry is a mechanical process industry. An old industry in both developing and developed countries, its technology has evolved slowly and is widely available from equipment manufacturers. It is probably the most widespread industry in developing countries. As of 1974 50 percent of the looms and 48 percent of the spindles of the world were installed in developing countries.\(^9\) It is also an industry in which large multinational corporations and foreign investment do not play an important role. U.S. multinational textile companies represented only 5.9 percent of the sales and 9.6 percent of the assets of all U.S. textile companies in 1966. This is compared against an average for all industries of 39.2 percent and 45.7 percent, respectively.\(^{10}\) Subsidiaries of multinational companies produce a negligible amount of the textile output of developing countries.

The pulp and paper industry is a chemical process industry for the most part. In its advanced industrial form, it is a new industry for developing countries. Its technology has evolved rapidly, is highly sophisticated, is mastered by only a few large firms, equipment manufacturers, and consulting companies, and is highly proprietary. It is not a common industry in developing countries. Developing countries produce only 5 percent of the world’s output of pulp and paper—an even lower percentage than their already low share of world consumption. Developed countries’ firms play a major role in this industry although this role is understated by the figures about multinational pulp and paper companies. Multinational companies account for only 21.8 percent of the sales and 24 percent of the assets of U.S. pulp and paper companies.\(^{11}\) These relatively low figures, however, are explained by the capacity of developed countries’ firms in this industry to resist
pressures to produce in developing countries. Although developing countries offer large wood resources and better growing conditions than do developed countries, the number of ventures in these countries by developed countries’ firms has remained small. At the same time few local firms have been able to put together the technical knowledge and the management skills needed to start such large ventures.

In each of these two industries, manufacturing activities—spinning and weaving of short staple fiber in textile and sulfate pulping of wood and papermaking in pulp and paper—were selected on the basis of two criteria: that the plants undertaking these activities be comparable in terms of their input and output and that the same range of alternatives be available for all technology choices.

Countries

Colombia, Brazil, Indonesia, and the Philippines were selected as the developing countries where manufacturing facilities were to be examined. The reason for their selection was that these countries are at different stages of industrial development, although all of these countries are relatively large. Large countries were chosen because of the need to have several textile and pulp and paper plants available for study in each country.

Country size might introduce a bias that would appear when extrapolating from the results of this study, however. The existence of a large market means that foreign companies and foreign equipment suppliers will automatically exhibit more interest. The presence of several producing companies in one industry also leads to a higher degree of competition. As will be shown later, these factors would lead to overestimating the propensity of firms to adapt to the local cost of the factors of production.

Production Facilities

For each industry a minimum of two production facilities was selected in each country, with the exception of Japan and the United States. The exact number of facilities selected depended upon the number of plants that satisfied the selection criteria used. Only in Brazil was the number of plants large enough to make it impossible to study all those that qualified.
The production facilities whose technology choices were to be studied were selected with two criteria in mind. First, their scales of production were to be as close as possible to each other in order to facilitate the matching of scale at the production step level. Second, their facilities, or at least part of their facilities, needed to have been constructed after 1970 and in operation at the time of the data collection (June 1975–April 1976). Within these constraints the companies were to have characteristics as varied as possible, in particular with regard to their ownership.

Table 1.2 shows the exact size and composition of the sample of firms on which this study was conducted. To the extent possible, the data collected from the production facilities and equipment manufacturers were based on actual operating conditions. Data collection for the manufacturing facilities normally took one to two days and for the equipment manufacturers half a day to a day, depending on the range of equipment they manufactured.

Definition of Some Concepts

The terms alternative technologies, choice of technology, adaptation, and appropriateness have been used so far without being defined. Although these concepts are fundamental to the technology choice issue, some of the controversy surrounding this issue can be traced to the different interpretations these terms receive in various disciplines, particularly in engineering and economics.

There are two basic definitions of technology: the engineering and the economic. To the engineer a technology is a transformation process, a way of combining inputs to obtain an output with given characteristics. It is thus primarily defined in terms of the operations and equipment it requires. Economists, on the other hand, define technology in terms of the type and quantity of each input, including capital, required to produce a given quantity of output, rather than in terms of the transformation process that takes place. To economists what engineers call a technology becomes a “black box” defined by what goes in and what comes out.

These two definitions of technology do not exactly coincide. Engineers will consider two production processes to be the same technology—or at most different techniques of production—as long as the principles and methods used are basically the same. This is despite the fact that the input mixes might be different. For economists this difference in
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The Choice-of-Technology Issue
input requirements will turn these two production processes into two distinct technologies.

Throughout this investigation the word technology is used in the economic sense. Minor changes in production techniques as well as fundamental process innovations are called different technologies if they result in differences in input requirements.

The concept of technology choice is based on the assumption that alternative technologies are available for the production of a given good. Again the engineering and the economic definitions of what should be considered alternative technologies differ widely. Such a divergence is attributable to the definition given by each discipline of what is to be construed as the same product.

For engineers a product is defined by a number of precise technical characteristics. A sheet of paper is defined by as many as twenty characteristics, measuring aspects as varied as its weight per unit of surface, its brightness, its smoothness, its resistance to burst and to tear, and its degree of absorption of water. A piece of cloth is characterized in the same way by some thirty variables, ranging from the characteristics of the yarn used in making the cloth to the types and number of imperfections in the cloth. Because of this degree of precision in the engineering definition of a product, practically no two processes or types of equipment can produce the same product. Therefore engineers will argue that once the product is defined, the number of alternative technologies available to produce it is very small, if there are any such alternatives at all.

In economic terms a product is defined by the need it fills and the market it is designed to reach. For economists the output of two different technologies becomes the same product if the market considers them as readily substitutable. Packaging papers that have a different resistance to burst and tear will be considered as different products in the economic sense, while slight variations in their color will not make them different products to an economist. Industrial backing cloth of different strengths or different shades of color will be considered as different products by engineers, but only different strengths will make them different products for the economist since different shades of color do not influence its end use.

In this study the decision to consider various technologies as alternatives for the production of a product is based on the economic definition of that product. No in-depth study, however, could be made of the substitutability of goods of different technical characteristics in
each of the markets served by the firms studied. Therefore the amount of arbitrary judgment involved in deciding what should be considered as alternative technologies was minimized by allowing only limited variations in the characteristics of the end product. Conceivably paper of the newsprint type, produced by a mechanical pulping process, could be sold as writing paper in Indonesia, given the lower quality requirements of that market. It would therefore be a substitute for the bleached caustic soda paper currently used, and these two technologies should be considered as alternative technologies. Since only an in-depth technical and market study could answer this question, however, the two technologies were not considered as alternatives in this study. Such restrictive behavior would result in an underestimation by this study of the range of alternative technologies available.

A choice between alternative technologies has to be made according to one or several criteria. An infinite number of criteria can be used to compare technologies and choose among them. One might want to select the newest technology or the technology that requires equipment that has the smallest number of moving parts. According to economic theory, however, the criterion to be used for a choice between alternative technologies should be the minimization of production cost. The use of this criterion in comparing alternative technologies leads to two concepts used throughout this study and that should therefore be defined: the concept of efficiency and that of adaptation or appropriateness.

On the basis of production cost minimization, a technology is considered as more efficient than another if it should always be chosen over the other, whatever the availability and price of the different factors of production. Such a situation will occur only if to produce a given quantity of a good, a technology uses less of some factors of production and an equal amount of the remaining factors as compared to another technology.

In most cases, however, alternative technologies combine the factors of production in such a way that each requires more of some factors of production but less of others than its alternatives. In such cases, one technology cannot be considered more efficient than its alternatives since their relative attractiveness will depend upon the cost of the various factors of production. It will then be decided that a technology is more adapted to a specific environment than another if it results in a lower cost of production given factor costs in that environment.
Because of some of its uses, the word *adapted* has gathered an ethnocentric connotation, implying that the technology suited to local conditions is the result of a transformation of the developed countries' technology. In this study the word *adapted* is used as meaning "suited" and therefore is interchangeable with the word *appropriate*. 