Macroeconomic Implications of Factor Substitution in Industrial Processes

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Prepared by: Howard Pack, Consultant
Development Economics Department

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The World Bank
1818 H Street, N.W.
Washington, D.C. 20433, U.S.A.

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MACROECONOMIC IMPLICATIONS OF FACTOR SUBSTITUTION IN INDUSTRIAL PROCESSES

This paper examines the scope for capital-labor substitution in the LDCs, that is, it is concerned with efficient alternatives to best-practice techniques used in the developed countries. It addresses three principal questions:

° How do the benefits to private producers of systematically adopting appropriate technology compare with those of adopting capital-intensive technology?

° How surmountable are the obstacles to adopting appropriate technology that is available?

° If the benefits of adopting appropriate technology are great and the obstacles surmountable, why are LDC producers opting for capital-intensive processes?

The analysis relies on engineering-economic analyses to answer the first question; a reformulation of obstacles in a cost-benefit framework to answer the second; and a discussion of alternative profit-seeking activities of producers to answer the third.

The summary at the front of this paper presents recommendations for lending practices and future research in the light of the findings.

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Revised
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Howard Pack

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SUMMARY AND CONCLUSIONS

This paper demonstrates that substantial social and private benefits can be obtained by systematically adopting appropriate technology rather than capital-intensive technology in modern manufacturing. By using a number of detailed engineering-economic analyses of existing production choices, it is found that value added in manufacturing can be increased 72 percent, nonwage income 51 percent, and employment and wage income 311 percent. These gains are upper bounds because they are based on the assumption that capital-intensive techniques now predominate in the less developed countries (LDCs). The gains nevertheless are independent of the use of shadow prices and would result solely from extending the range of technology considered and adopted by firms. Moreover the technologies constituting that range already are in use in some private factories. They consequently can be immediately disseminated, unlike those proposed by advocates of intermediate technology, which has not yet been developed.

In the light of the magnitude of benefits that can be derived, it is shown that many of the objections to the use of more labor-intensive production processes—such as their allegedly greater skill requirements—must be reformulated within a benefit-cost framework. For example, in two sectors in which the appropriate technology is in fact more skill-intensive, calculations show that the benefit-cost ratios from the training of workers to allow the adoption of this technology are 35 and 63.

The failure of many LDC firms to use available technology is then explored. A given firm has a large number of alternatives for improving its profits. These range from increasing the efficiency on the plant floor to
assuring the availability of intermediate inputs. The addition to profits that might be obtained from these efforts is of roughly the same magnitude as that from an appropriate choice of technology. Insofar as firms find it less costly to increase profits by making efforts to improve efficiency (broadly defined), they would concentrate on these efforts rather than search for and choose appropriate techniques, unless the costs of acquiring information about those techniques can be reduced. This interpretation is buttressed by the evidence now accumulating: despite the fact that multinational corporations locating in LDCs face higher wage rates and lower borrowing costs, they exhibit factor proportions that are similar to or more labor-intensive than those of locally owned firms manufacturing the same product. Such behavior probably is attributable to the costs of information about alternative technologies, costs which are lower for multinational corporations because of their ready access to other subsidiaries and their ability to purchase through the home office.

**Implications for World Bank Lending Practices**

The following discussion proceeds from steps that could yield benefits quite quickly to those whose payoff is more distant. Even steps having a distant payoff are worth undertaking, however, because they promise greater benefits and present the greatest long-run hope for generating employment.

**Choosing consulting engineers.** The Bank finances industrial projects directly through its own lending and indirectly through development finance corporations. Although there is some attention to the choice of technology, it is not accorded a high priority. One method to increase the range of choice considered for projects would be to revise the feasibility
studies by consulting engineers. Consulting engineers could be required to present a detailed costing for several levels of technology, which might be defined in relation to the process or the aggregate equipment costs per project. They could also be asked to provide a profile of the production techniques in several countries at different stages of development and to indicate why techniques differing from their ultimate recommendation are unsuitable. Another method to increase the range of technological choice on projects would be to require parallel efforts by two consulting engineers, one from a developed country, one from an LDC. Because the range of knowledge possessed by consulting-engineering firms appears highly localized and often spans no more than a few equipment producers, LDC firms probably are more familiar with equipment produced in LDCs or less expensive equipment produced in developed countries. Moreover LDC firms may be more ready to consider nonmechanized devices for material movement and handling.

Either method would generate useful side benefits. Consulting-engineering firms, by having to provide alternatives, would enable lending institutions to accumulate a "shelf" of technologies against which future feasibility studies could be checked. Encouraging consulting engineers in LDCs should increase their competence and provide important incentives to local capital-goods producers, who may begin to perceive heretofore unseen opportunities for exports.

**Disseminating knowledge.** Although there has been considerable financing of agricultural extension services, little if any concessional aid has been directed toward improving manufacturing practices and broadening knowledge of industrial technology. Agricultural extension services have
largely been government-operated, but it is not certain that the diffusion of knowledge in the industrial sector is best achieved in a similar manner. A variety of mechanisms might be tried and evaluated on an experimental basis: the financing of local firms specializing in technology, including plant operating procedures; information services provided by development finance corporations; extension services modeled on those for agriculture. To determine the comparative effectiveness and the social benefit-cost ratios of these mechanisms, the experiments would have to be designed in a way that is specific to countries and sectors. Because of the total absence of knowledge in this area and the potentially large payoffs, such an effort would clearly be worth while.

Encouraging trade in used equipment. In one sector analyzed, textile spinning, the availability of used equipment is an important element of technical choice. The same is likely to be true in other sectors. Evidence is accumulating in countries as diverse as Colombia and Japan that small and medium-sized companies have been intensive users of used equipment. There nevertheless are some noticeable imperfections in the market for used equipment, including the difficulty of identifying quality equipment, the problem of obtaining financing, and the possibility that performance specifications will not be reestablished after equipment is disassembled, transported, and reinstalled. Thus individual firms face risks, even though the social return associated with having a large number of firms adopt such equipment would be substantial. Lending agencies have a number of opportunities for intervention: one is financing the foreign exchange component of insurance programs that national governments might set up to protect individual firms.
Encouraging the production of capital goods by LDCs. If the encouragement of LDC capital-goods production were to lead to the manufacture of plant equipment that is appropriate to LDC factor endowments, the problem of disseminating information would be reduced because such producers would find their markets in LDCs. The sales efforts of these companies would presumably have the same impact as the efforts of salesmen from developed countries in influencing the choice of equipment. A long-run solution requires augmenting and improving the production capacity of LDCs, a requirement that could be decisively affected by direct lending and technical aid to the capital-goods sector. 1/ In the short run, such agencies as the World Bank can encourage greater trade between LDCs by establishing wider networks for the provision of equipment on industrial projects. Directing improved advertising of proposed projects at producer firms rather than ministries of industry would be a useful beginning. 2/ Similarly, the improvement of financial facilities, particularly guarantees of performance, could be encouraged and partially financed by international agencies.

Implications for World Bank Research

Each of the foregoing implications for lending practices implies two kinds of research effort: obtaining a more secure base of knowledge in the areas discussed; monitoring the social benefits and costs of any

1/ These issues are discussed at length in Pack (1979b) and in a recent study on the machinery sector in South Korea (World Bank 1978).

2/ This would require broadening the distribution and amplifying the scope of the business edition of Development Forum, a twice-monthly U.N. publication that provides subscribers with information about sales opportunities associated with loans by the World Bank and the regional development banks.
programs that are undertaken. In addition, the set of research topics not
directly tied to lending efforts can be broadened to reduce some substantial
lacunae in current knowledge.

Empirically describing and analyzing current mechanisms for dissemin-
ating technical knowledge in LDCs. After determining how these mechanisms
work, there should be social cost-benefit analysis of their impact and com-
parisons among institutions. Ideally such a study would proceed from a study
of the institutions and a sampling of firms, the latter to determine whether
those not receiving technical information exhibit different behavior with
respect to technology and whether such differences are quantitatively signi-
ficant. In a survey of firms, more basic knowledge could be accumulated,
including the determinants of technology choice, the attitudes toward risk,
and the effect of improved technical choices on private profits. Despite the
large number of studies designed to demonstrate the existence of efficient
substitution possibilities, there is little direct evidence on the underlying
behavior of firms.

Studying issues related to the market for used equipment. These
issues include the structure and performance of the used equipment market,
the record of firms that have purchased used equipment, the performance of
LDC trading companies that specialize in used equipment, and the risks in
sectors in which the technology is rapidly changing. 1/

1/ On some of these issues, see Yung W. Rhee, "Back-to-Office Report on
Visit to the International Textile Machinery Show," May 1978 and Mariluz
Cortes, "Notes on the First Small and Medium Scale Enterprise Survey in
Colombia: The Mechanical Engineering Sector," August 1978. Both are
internal memoranda of the World Bank's Economics of Industry Division.
Systematically surveying the activities of LDC capital-goods producers. Surveys of the extent and character of these activities should be undertaken in the principal producer countries: Argentina, Brazil, India, Korea, Mexico, Pakistan, and Taiwan. The questions to be considered would be related to efficiency, the capacity for innovation, and the ability to alter factor proportions.
INTRODUCTION

In recent years a number of investigators have carried out studies to determine the possibilities for efficiently substituting labor for capital in manufacturing. The products for which they have delineated substitution possibilities are typical of the modern sector and include shoes, beer, cotton textiles, refined sugar, and milled maize. These and similar products constitute a significant part of the industrial production existing or proposed in many LDCs. This body of empirical research has not considered substitution options in either small-scale manufacturing or cottage enterprises. Nor has it considered the efficiency of production in smaller units relative to that in larger scale manufacturing. This paper surveys some of the principal studies in this genre, assesses some of their aggregate quantitative implications, and identifies a number of policy issues, particularly the forces militating against the adoption of appropriate equipment, even when it exists.

The studies that set forth a complete isoquant for producing a given product can be differentiated from two earlier sets of empirical efforts to determine the possibilities for factor substitution in manufacturing: that is, econometric estimates of the elasticity of substitution, and studies demonstrating substitution possibilities but not establishing their quantitative importance. 1/

---

1/ Substitution possibilities have been summarized and evaluated in a number of surveys. Two emphasizing primarily the econometric evidence are those of Gaude (1975) and Morawetz (1976). The reviews by Acharya (1974), Morawetz (1974), Stewart (1974), and White (1978) are more inclusive.
Most analysis before 1970 relied on statistical estimation of the elasticity of substitution, usually for products at the two-digit ISIC level. Elasticities significantly above zero were found for many industries, suggesting considerable scope for factor substitution. Although encouraging, such results could not, by themselves, constitute the basis for the efforts needed to induce more labor-intensive production. The typical procedure used to estimate the elasticity of substitution requires confidence in the meaning of the regression of value added per worker on the real wage. Moreover almost all these studies were conducted at the two-digit level, and specific results were influenced by differences in product mix. At the least, some engineering or factory-specific data needed to be adduced to corroborate their findings.

Partly in response to the uncertainty inherent in the purely econometric studies, a second group of investigators visited factories in LDCs to ascertain the technology actually being used and the character and scope of adaptation to local factor prices (Pack 1976, Ranis 1973, and Wells 1973). Much of this literature confirmed the existence of options for efficiently increasing the labor intensity of production. In some manufacturing activities the principal substitution options were found at the core of production, such as spinning yarn or shaping and heating cement blocks. Lower capital intensity was attributable to the use of equipment lacking labor-saving devices or explicitly designed for use at low volumes. In some cases this equipment remains in production; in others it must be acquired after being

1/ Acharya's survey (1974) indicates some of the difficulties of interpreting the statistical results.
discarded by firms in developed countries. In addition to the use of labor-intensive equipment in core production, labor-intensive operation has been found to be feasible in such peripheral activities as moving material, packaging, and storing.

The more systematic analyses upon which this paper is based—those combining engineering and economic analysis of production—represent a third generation of explorations of factor substitution. Because they set out fairly complete isoquants, it becomes possible to answer questions about the aggregate implications of factor substitution and to reformulate some of the doubts expressed about the viability of labor-intensive technologies into a numerical benefit-cost framework.

The third-generation microeconomic studies use both engineering information and data obtained from visits to plants in LDCs. This information is then used in two different ways. The first method measures the inputs that operating plants require to produce a well-defined product in a country or group of countries. 1/ Differences in production within a country may reflect different knowledge among entrepreneurs of available techniques, variation in factor prices paid, licensing arrangements with foreign firms, and other factors. Differences in production between countries may reflect similar factors. Given the observed inputs of capital, labor, and materials, a set of efficient techniques can be delineated in the sense that each technique is a point on an isoquant. 2/

---


2/ A set of efficient techniques, in comparison with any combination of inefficient techniques, produces a given level of output using less of at least one input and no more than the same quantity of other inputs.
The second method, used in studies carried out at the University of Strathclyde, relies on the construction of synthetic isoquants. 1/ By using data obtained from individual factories in a large and varied set of countries, as well as engineering information, a set of alternative techniques is identified for each stage in production. By assuming that the choice at one stage does not limit the range of choice in preceding or succeeding stages, synthetic technologies consisting of combinations of known techniques are constructed. Thus, if there are three production stages and if four techniques are identified for each, sixty-four synthetic technologies are defined. After completing this artificial construct, inefficient techniques are weeded out, and the optimal technology is found by computing the present discounted value (PDV) of operations for each of the efficient techniques. 2/

I will not further describe the two methods at this point, but will introduce additional detail where appropriate. Although questions of interpretation persist, such as the definition of the value of capital in studies that rely on information about plant operations, the microanalytical work has the merit of less reliance on the strong assumptions embodied in statistical studies of the constant-elasticity-of-substitution production function. That work also has the appeal of the concrete: not only can the curvature of a given isoquant be determined; the specific set of interrelated machines and processes corresponding to a given capital-labor ratio can also be identified. In addition, it is possible to link each of these

1/ See Disney and Aragaw (1975), Huq and Aragaw (1977), Keddie and Cleghorn (1975 and 1977), Uhlig and Bhat (1976), and University of Strathclyde (1975).

2/ See note 2 on page 3.
techniques to a particular engineering process, such as weaving cotton with a loom having a particular weft-injection mechanism or sealing cans with machines originating in several different countries. Thus, if efficient factor substitution is found to be feasible, it is possible, in principle, to direct an LDC ministry or business to the actual producer.

There have been only a few efforts to aggregate microeconomic substitution possibilities. 1/ That by Roemer, Tidrick, and Williams investigates the implications for aggregate employment of a labor-intensive strategy in Tanzania but does not systematically use the microeconomic studies of substitution now available. Thus the range of capital-labor ratios in their work is narrower than that found in the more recent studies. Similarly, without a fully articulated isoquant, they cannot explicitly derive the optimal factor mix by using relevant factor prices, but must assume that one of only two available techniques is adopted. They find that the increase in the number of jobs in the industrial sector over a twenty-year planning horizon could be 35 percent higher with a labor-intensive strategy than with a capital-intensive strategy; the increase in value added, 6 percent higher. Both magnitudes, in the light of more recent knowledge about various industrial branches, are likely to be underestimates. Their work nevertheless demonstrates the scope for simultaneously increasing employment and output, though it leaves doubt about the numerical range.

1/ See Tokman (1975) and Roemer, Tidrick, and Williams (1975). Tokman does not use existing studies of actual alternative production processes. Instead labor intensities are derived from data on average labor productivity of firms of different size within each industry; these observed labor intensities are then used to represent the available choice of technology.
The first section of this paper describes the assumptions used in deriving aggregate benefits from these third-generation studies. The second section presents the principal findings of calculations of the potential aggregate benefits to be derived from existing substitution possibilities. The third section analyzes the production relations in more detail. The fourth section considers some of questions which pessimists typically invoke about the prospects for labor-capital substitution in LDC industry and shows that the obstacles may not be as considerable as is conventionally perceived. The last section outlines a few of the policy options raised by the preceding discussion.

ASSUMPTIONS

To calculate the benefits that can be realized from the correct choice of technology, I make certain assumptions about the mix of products, the markets for factors and products, and the range of technological choice.

Product Mix

This study assumes that the same investment, $100 million, is made in each of nine sectors: shoes, woven cloth, yarn, bricks, milled maize, processed sugar, beer, leather, and fertilizer. 1/ The list of products could be augmented only by relying on empirical observations that are less systematic than those used here. Because realized benefits would depend on the sectoral mix of investment and the success in altering factor proportions, the

1/ See pages 18-20 for a brief discussion of other available studies. They are not included in the following calculations because they would give disproportionate weight to a few sectors.
aggregate benefits calculated in the next section are best viewed as suggesting rough orders of magnitude. There nevertheless are two grounds for believing that the estimates of aggregate effects are unlikely to be greatly changed as studies of additional sectors become available. First, the products considered include those about which it usually is assumed that factor substitution is at least physically possible—shoes, yarn, and woven cloth—as well as those about which conventional wisdom asserts that not much variation is permitted in factor proportions—fertilizer and beer. 1/ Second, the shares of food, beverages, and textiles in manufacturing in the sample roughly correspond to those in poorer LDCs (table 1).

Factor and Product Markets

In calculating the benefits to be derived from a correct choice of technique, I will use market prices of factors in typical poorer LDCs, such as Indonesia, India, and those in Sub-Saharan Africa. In particular, I assume the wage of unskilled workers to be $500 a year, the interest rate 10 percent a year. The former probably is above, the latter below, its scarcity price. Shadow pricing, however desirable it may be, currently encounters financial and administrative obstacles, to say nothing of the constantly changing views about correct estimation. Consequently the use

1/ The sectors considered can be divided into those in which employment is, or is not, sensitive to the choice of production method. Thus, in weaving, the use of a given loom may triple the level of employment per square yard of cloth produced, whereas employment in beer brewing will not be much affected by the technology chosen. In the latter case, however, a given level of output can be produced with a range of investment outlays, permitting the realization of variation in the capital-output ratio, though the labor-output ratio does not vary much by technique. The capital-labor ratio is altered, and this is the variable of interest.
Table 1. Shares of Value Added and Current Investment in Manufacturing, Selected Sectors and Countries (percent)

<table>
<thead>
<tr>
<th>Country</th>
<th>Year</th>
<th>Food</th>
<th>Beverages</th>
<th>Textiles</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td></td>
<td>Value added</td>
<td>Current investment</td>
<td>Value added</td>
</tr>
<tr>
<td>Ecuador</td>
<td>1973</td>
<td>28</td>
<td>28</td>
<td>9</td>
</tr>
<tr>
<td>Egypt</td>
<td>1972</td>
<td>16</td>
<td>11</td>
<td>1</td>
</tr>
<tr>
<td>Indonesia</td>
<td>1973</td>
<td>35</td>
<td>34</td>
<td>2</td>
</tr>
<tr>
<td>Kenya</td>
<td>1971</td>
<td>15</td>
<td>26</td>
<td>10</td>
</tr>
<tr>
<td>Korea</td>
<td>1973</td>
<td>6</td>
<td>7</td>
<td>6</td>
</tr>
<tr>
<td>Philippines</td>
<td>1973</td>
<td>27</td>
<td>27</td>
<td>5</td>
</tr>
</tbody>
</table>


/\ Included with food.
of market prices provides the basis for realistically measuring the benefits to be obtained from correct choices of technique or, more precisely, from searching for and implementing appropriate technology.

The macroeconomic context is assumed to be one in which the incremental output of the manufacturing sector can be sold without a deterioration in the product prices assumed in the calculations or an increase in factor prices paid by the sector. This assumption for product markets can be interpreted as reflecting the growth of a relatively small industrial sector in an economy dominated by an agricultural sector that is sufficiently developed to absorb industrial output without a decline in the terms of trade. Alternatively the assumption can be interpreted as reflecting an industrial sector that is relatively small and directs its incremental output into exports without affecting prices.

I assume that worldwide production capacity in the capital-goods sector is sufficient to supply the equipment required. This assumption implies an intermediate-term scenario, because large increases in demand are usually met by lengthening delivery times rather than by quickly expanding capacity. I also assume that the depth of ability of managers and operatives is sufficient to enable a larger number of smaller plants to be established simultaneously. Often the justification of one very large plant, usually capital-intensive, rather than several smaller ones is the presumed economizing of scarce organizational skills. If this presumption affects the choice of technique, it constitutes a case for investing in skills rather than continuing to choose technology that reflects these constraints.

Techniques

Of the large range of feasible production techniques, two will be compared: the most capital-intensive technique, and the appropriate technique,
defined as that which yields the maximum ratio of present discounted value (PDV) to capital cost. The criterion for appropriate technology assumes a situation in which the sectoral allocation of investment funds is fixed and every firm within a sector attempts, given the constraint on investable funds, to maximize its PDV. 1/

Table 2 presents data on fixed investment and employment for the most capital-intensive technology and the appropriate technology in the nine sectors. The capital-intensive technology may be thought of as a turnkey plant designed by a consulting engineering firm or a diversified equipment producer, though LDC producers may themselves design such a plant. The various studies surveyed indicate that such a plant is not as mechanized as an advanced factory in a developed country because the synthetic isoquants exclude plant features rarely found in LDCs, such as overhead cranes. Thus even the capital-intensive technologies reflect some adjustment of factor proportions to local endowments. On the other hand, the appropriate technology is not necessarily the most labor-intensive. In five of the nine sectors, even more labor-intensive technologies are available, but they would become privately competitive only at shadow prices.

The range of capital-labor ratios within sectors is considerable, as is the range across industries. In all sectors except spinning, the basis of the investment cost per worker is the prevailing price of new equipment; in spinning the variation in price is explained by the lower price of used

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1/ In some of the underlying sectoral studies (beer brewing, brickmaking, and leather processing) the PDV/K ratio is not available for all technologies, and I have used the characteristics of the technology with maximum PDV.
Table 2. Fixed Investment and Employment Associated with Capital-intensive and Appropriate Technologies

<table>
<thead>
<tr>
<th>Sector</th>
<th>Annual output of plant</th>
<th>Capital-intensive technology</th>
<th>Appropriate technology /a</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td></td>
<td>Investment in thousands of dollars</td>
<td>Thousands of workers per worker</td>
</tr>
<tr>
<td>Shoes</td>
<td>300,000 pair</td>
<td>334</td>
<td>155</td>
</tr>
<tr>
<td>Cotton weaving</td>
<td>40,000,000 square yards</td>
<td>9,779</td>
<td>260</td>
</tr>
<tr>
<td>Cotton spinning</td>
<td>2,000 tons</td>
<td>1,440</td>
<td>98</td>
</tr>
<tr>
<td>Brickmaking</td>
<td>16,000,000 bricks</td>
<td>3,437</td>
<td>75</td>
</tr>
<tr>
<td>Maize milling</td>
<td>36,000 tons</td>
<td>613</td>
<td>63</td>
</tr>
<tr>
<td>Sugar processing</td>
<td>50,000 tons</td>
<td>6,386</td>
<td>1,030</td>
</tr>
<tr>
<td>Beer brewing</td>
<td>200,000 hectolitres</td>
<td>4,512</td>
<td>246</td>
</tr>
<tr>
<td>Leather processing</td>
<td>600,000 hides</td>
<td>6,692</td>
<td>185</td>
</tr>
<tr>
<td>Fertilizer</td>
<td>528,000 tons of urea</td>
<td>34,132</td>
<td>248</td>
</tr>
</tbody>
</table>

Note: Detailed descriptions of the characteristics of technical choices constituting the basis of this analysis will be set out in a forthcoming paper.

Sources: Shoes from University of Strathclyde (1975); cotton weaving and cotton spinning from Pack (1975) and Shirley Institute (1978); brickmaking from Keddie and Cleghorn (1977); maize milling from Uhlig and Bhat (1976); sugar processing from University of Strathclyde (1975); beer brewing from Keddie and Cleghorn (1975); leather processing from Huq and Aragaw (1977); and fertilizer from Disney and Aragaw (1975).

/a Technology yielding the maximum PDV relative to capital.
equipment. In all cases the cost comparisons, which determine the appropriate technology, reflect the effects of raw material use, power, and working capital as well as primary inputs.

The technical choices considered here reflect prior calculations of efficient scale. Thus, in operations for which scale economies exist, the annual capacity of the plant is that at which further scale economies in production have been found to be negligible using a given technology (see the figures on output in table 2). Indeed most of the studies surveyed probably are conservative in their evaluation of smaller scale plants: they devote considerably more effort to determining efficient isoquants and their costing than to transport and marketing, which nevertheless are analyzed in several sectors. Thus smaller plants with typically higher labor intensity have been ruled out as inefficient, even though a more detailed specification of transport and marketing systems might reveal that they have the same private and social profitability as larger plants. If this were true, the estimates of this paper would be understatements of the potential benefits from correct choice of technology.

1/ Some issues associated with used equipment will be considered in the section, Additional Questions about Appropriate Technology. Used equipment is not, however, the only source of variation in spinning.
AGGREGATE BENEFITS STEMMING FROM CORRECT CHOICE OF TECHNIQUE

Consider a country undertaking an expansion in industrial capacity and allocating the same amount of investment funds, $100 million, to the production of each product listed in table 2. Given the expansion that is planned, I initially calculate the magnitudes of principal interest—national income originating in these projects, total wages, and the amount of employment—assuming that the funds are expended on the most capital-intensive process or on the most appropriate process, as measured by maximum PDV/K. Because I assume that market wages prevail, the benefits derived are attributable solely to the correct search for and choice of technique, not to the adjustment of factor prices to shadow prices.

Let I denote the investment allocated to each industry, a the most capital-intensive technique, b the appropriate technique, $K_a$ or $K_b$ the investment required for one efficient plant, and $Y_a$ or $Y_b$ the associated present discounted value of nonwage income from one such plant. $K_a$ and $K_b$ include requirements for both fixed and working capital. The gain in the present discounted value from the choice of b rather than a is:

\[ \Delta Y = I \left( \frac{Y_b}{K_b} - \frac{Y_a}{K_a} \right). \]

This equation assumes that fractions of projects can be undertaken, even in such capital-intensive sectors as urea production, and that investment funds

---

1/ I concentrate on the implications of correctly using one year's investment funds. Investment, of course, continues year after year, and the changes found here would be cumulative. More complex computations could be made using greater detail about the investment profile in each project, changes in the availability of investment funds in each period, and so on, but the simpler case dealt with here highlights most of the relevant issues.
saved by the choice of appropriate techniques \((K_a - K_b)\) can be invested in the sector, even at a fraction of the initial scale. 1/ Changing this assumption by allowing the saved funds to be reinvested in one of the divisible labor-intensive sectors would, of course, increase the aggregate benefits but change the product mix, which is being held constant.

The annual value of the nonwage share of additional income originating in manufacturing is the average annual value of \(\Delta Y\), or:

\[
\bar{Y} = \Delta Y \left(\frac{1}{A_{\text{in}}}\right),
\]

where \(A_{\text{in}}\) is the present discounted value of an annuity of one dollar for \(n\) years earning interest at \(i\) percent. The interest rate used is 10 percent, and the period typically is twenty-five years, though it varies by industry. 2/

The effects on employment and wage income can be similarly derived. Let \(z_a\) and \(z_b\) denote the capital-labor ratios corresponding to the two plants in an industry. Then the total employment generated by investment of \(I\) in the two techniques is \(I/z_a\) and \(I/z_b\), and the increase in employment stemming from the appropriate choice is:

\[
N_b - N_a = I \left(\frac{1}{z_b} - \frac{1}{z_a}\right).
\]

1/ There are, in fact, likely to be many products exhibiting the same high capital-labor ratio but a lower total investment requirement.

2/ It would be possible not to convert all nonlabor value added to a present discounted value in the first place and directly to use the annual flows. But some of the studies do not present a detailed time-profile of costs and simply indicate that they vary over time. I thus have used the present discounted values that they do present. Moreover, insofar as there are uneven flows, annualized PDVs allow more convenient comparisons.
Given the assumed annual wage of $500, the difference in the average annual wage bill is:

\[ \Delta W = (N_b - N_a) \times 500. \]

Table 3. Annual Employment, Wage and Nonlabor Income, and Value Added under Alternative Technologies

<table>
<thead>
<tr>
<th>Sector</th>
<th>Employment (workers)</th>
<th>Wage income (----------millions of dollars----------)</th>
<th>Nonlabor income (----------millions of dollars----------)</th>
<th>Value added (----------millions of dollars----------)</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>Appropriate intensive</td>
<td>Capital-intensive</td>
<td></td>
<td>Appropriate intensive</td>
</tr>
<tr>
<td>Shoes</td>
<td>31,589</td>
<td>18,158</td>
<td>15.79</td>
<td>9.08</td>
</tr>
<tr>
<td>Cotton weaving</td>
<td>10,488</td>
<td>2,538</td>
<td>5.24</td>
<td>1.27</td>
</tr>
<tr>
<td>Cotton spinning</td>
<td>10,747</td>
<td>4,525</td>
<td>5.37</td>
<td>2.26</td>
</tr>
<tr>
<td>Brickmaking</td>
<td>29,909</td>
<td>2,182</td>
<td>14.95</td>
<td>1.09</td>
</tr>
<tr>
<td>Maize milling</td>
<td>19,231</td>
<td>7,574</td>
<td>9.62</td>
<td>3.79</td>
</tr>
<tr>
<td>Sugar processing</td>
<td>123,980</td>
<td>15,925</td>
<td>61.99</td>
<td>7.96</td>
</tr>
<tr>
<td>Beer brewing</td>
<td>7,460</td>
<td>4,316</td>
<td>3.73</td>
<td>2.16</td>
</tr>
<tr>
<td>Leather processing</td>
<td>4,502</td>
<td>2,108</td>
<td>2.25</td>
<td>1.05</td>
</tr>
<tr>
<td>Fertilizer</td>
<td>772</td>
<td>691</td>
<td>0.39</td>
<td>0.35</td>
</tr>
<tr>
<td>Total</td>
<td>238,678</td>
<td>58,017</td>
<td>119.33</td>
<td>29.01</td>
</tr>
</tbody>
</table>

Note: See the note to table 2.

Source: Calculations based on data in the sources listed in table 2.

\* The technology assumed is synthetic (see page 4). Thus the negative value added is not generated by the technology actually in use in any operating plant.
Table 3 presents the results of these calculations by sector. Table 4 summarizes the substantial differences between the two regimes. Under the uniform choice of appropriate rather than capital-intensive techniques, the annual value added in manufacturing increases 72 percent, employment 311 percent, and nonlabor income 51 percent. The capital-labor ratio for all manufacturing is reduced 76 percent, value added per worker 58 percent. The increase in nonwage income undercuts the arguments of those who view capital-intensive projects as necessary to generate reinvestment out of profits, even at the sacrifice of short-term employment and wage income. Although the share of nonwage income declines, its absolute value increases.

Table 4. Summary of Results Presented in Table 3

<table>
<thead>
<tr>
<th>Technique</th>
<th>Value added (millions of dollars a year)</th>
<th>Wage income (dollars)</th>
<th>Nonlabor income (dollars)</th>
<th>Employment (workers)</th>
<th>Capital-labor ratio (dollars per worker)</th>
<th>Value added per worker (dollars)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Appropriate</td>
<td>624</td>
<td>119</td>
<td>505</td>
<td>238,678</td>
<td>3,771</td>
<td>2,614</td>
</tr>
<tr>
<td>Capital-intensive</td>
<td>364</td>
<td>29</td>
<td>335</td>
<td>58,017</td>
<td>15,513</td>
<td>6,274</td>
</tr>
</tbody>
</table>

Source: Table 3.

It is important to note that the increase in value added in modern-sector manufacturing shown in table 3 is not equivalent to additional national income. The dynamic effects of the additional investment made possible by increased income are omitted because their calculation would require more detailed specification of the general macroeconomic context, including the different savings propensities for different types of factor incomes. Clearly this omission leads to still another understatement of the benefits to be derived from following a labor-intensive path.
income for the entire economy. The creation of more jobs in the modern sector implies, with a given labor force, that fewer workers would be employed in the urban informal and rural sectors. Workers who would otherwise have been employed in lower income jobs in these sectors are now employed in the modern sector. In contrast with their situation in the lower income pursuits, each is endowed with a higher capital stock, produces more output, and receives a higher wage. Insofar as those workers previously were productive, the output forgone as a result of the reallocation of labor must be subtracted from the additional wage income in modern manufacturing to obtain the net increase in national income. Although the computed gains are gross, not net, the net gains would certainly be positive.

The additional returns to capital, on the other hand, are in fact a net gain: the marginal product of each dollar of capital allocated to the modern sector is higher as a result of being used in conjunction with more labor. 1/ Whether such income is true social income depends on a number of characteristics of an economy, including imperfections in the product market caused by trade distortions. Pursuing these characteristics would take the discussion far afield, and the additional nonwage income is best viewed as indicating rough orders of magnitude.

From the sectoral detail of table 3 it can be seen that all branches contribute to the computed gains. Substantial additional income is generated even in such capital-intensive sectors as brewing and leather processing; larger gains are achieved in sectors, such as shoes, commonly perceived to permit greater substitution.

1/ Although the reduction of labor in the nonmodern sector would reduce its marginal product of capital, this loss would be relatively small for the entire economy, given the small capital stock of that sector.
Additional comment may add some perspective to the results of table 3. In weaving, the appropriate technology adopted is the conventional automatic loom. Other evidence not reflected in table 2 suggests a still richer set of options. For example, Rhee and Westphal (1977) have demonstrated that Korean textile producers manufacture internationally competitive cloth with semiautomatic looms that are locally built. Because these looms are capable of high-quality production (at least when manned by Korean workers) and are considerably less expensive than automatic looms from Europe, incorporation of this loom in the computations would increase the benefits. 1/ Korean machinery producers also manufacture automatic looms whose characteristics would also place them on the efficient isoquant. In a similar vein, production of 1965-vintage textile equipment, in both spinning and weaving, is found in India, and this would also extend the range of relevant substitution possibilities (World Bank 1975). Amsalem (1978, table 5-1) has recently identified LDC-produced spinning-room equipment that would also extend the range of choice.

Still other sectoral studies not included in tables 2 and 3—those examining nuts and bolts (Uhlig and McBain 1977), aspects of bicycle production (Lamyai, Rhee, and Westphal 1978), can-sealing operations (Cooper and others 1975), and foundries (Bhat and Prendergast 1977)—also demonstrate numerically the substantial range of extant technical choice. Substitution possibilities in these production operations have not been included in the

1/ This has not been done because of some uncertainty about whether products of similarly high quality could be obtained in other countries.
computation of potential gains in table 3 because they concentrate on only a few stages of production, which makes it difficult to assess the quantitative significance of factor substitution for the entire production process. In addition, some detailed studies—on sugar refining (Baron 1975) and cement blocks (Stewart 1975)—have not been included because of the coverage of similar or identical products in the more comprehensive Strathclyde studies. Furthermore several careful studies—on petrochemicals (Morawetz 1975) and rice milling (Timmer 1972)—have been excluded to avoid too large a representation of particular industries. The absence of substitution in petrochemicals would duplicate that of fertilizer production and tend to lend too heavy a weight to sectors not yet important in the LDCs I have in mind. The extensive substitution possibilities found by Timmer in rice milling would simply replicate that in maize milling, but give too heavy a weight to food processing.

Nevertheless, to provide some flavor of the results not included in the computation of potential income gains, some of the excluded material is shown in table 5. The range of efficient substitution is, if anything, larger than that for the production processes shown in table 2 and reinforces the findings of considerable possibilities for substitution. Some of the choice derives from the availability of equipment from producers outside Europe and America. For example, the least-cost technique in rice milling—with an investment cost of $847 per worker, compared with $66,819 per worker for the most capital-intensive technology—uses equipment produced in Japan, whereas the more expensive technology is manufactured in Western Europe. There are other interesting issues underlying these data, but I return to the main body of results that I intend to analyze.
Table 5. Capital-Labor Substitution in Other Manufacturing Activities

<table>
<thead>
<tr>
<th>Activity country</th>
<th>Capital-labor ratio (dollars per worker)</th>
<th>Technique</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td></td>
<td>1</td>
</tr>
<tr>
<td>Can making</td>
<td></td>
<td>170</td>
</tr>
<tr>
<td>in Thailand</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Round can making</td>
<td></td>
<td>4,190</td>
</tr>
<tr>
<td>in Kenya and Tanzania</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Kerosene can making</td>
<td></td>
<td>4,447</td>
</tr>
<tr>
<td>in Kenya and Tanzania</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Rice milling</td>
<td></td>
<td>0</td>
</tr>
<tr>
<td>in Indonesia</td>
<td></td>
<td></td>
</tr>
</tbody>
</table>

-- Not applicable.

* Least-cost technique.

Sources: Data on can making from Cooper and others (1975); that on rice milling from Timmer (1972).
Importance of Sectoral Composition

It is obvious from the data in table 2 that the sectoral composition of investment strongly influences the variables of interest. Among the capital-intensive technologies, fertilizer production exhibits three times the capital-labor ratio of brickmaking, the next most capital-intensive activity, and sixty times that of shoe production. These multiples increase when the appropriate technologies are compared. Each line in figure 1 connects the capital-labor ratio of the capital-intensive technique on the vertical axis and that of the appropriate technique on the horizontal axis. The figure demonstrates, with the exception of fertilizer, that there is no unique ranking of capital intensity when all sectors are considered: that is, sector i may be more capital-intensive than sector j when only capital-intensive technologies are compared, but more labor-intensive when appropriate technologies are compared. This can be seen by the frequency of intersecting lines. The payoffs in additional employment and additional output from correct sectoral choice can be quite large relative to the gains from correct intrasectoral choice of technique. Exploiting the scope for factor substitution between sectors has been important in the countries considered to be successful in generating productive employment, though the choice of technique within sectors has also played a role. Given the difficulties of implementing choices of optimal technology, even if the techniques are readily available, the potentially simpler and more powerful process of altering the product mix, particularly through exports, must be kept in mind.
Figure 1. Comparison of Capital-intensive and Appropriate Techniques, by Activity
Evidence of Inappropriate Technical Choices

It must be noted that the gains calculated in table 3 should be viewed as maxima, because it is likely that LDC firms often choose techniques which are more labor-intensive than the most capital-intensive technique shown in table 2. There is limited direct evidence of the extent of inappropriate choice of equipment. Most studies of factor substitution based on visits to LDC plants have found some adaptation to local factor prices (Cooper and Kaplinsky 1975, Pack 1976, Ranis 1973, Rhee and Westphal 1977, and Timmer 1972). Similarly, comparisons of factor choices by multinationals and local firms have indicated that the technology of developed countries rarely is completely replicated in the LDC by either type of firm (see the discussion on pages 48-51).

The only systematic study using engineering data to examine the appropriateness of technical choices at the firm level is that by Amsalem (1978). Having determined the isoquant that would be faced by a fully informed firm engaging in integrated textile production, he compares the optimal (cost-minimizing) static technique at both market and shadow prices. For my purposes the optimal technique at market prices is of interest. Of 112 decisions (seven stages of production for sixteen firms) the following distribution of equipment choices is found (Amsalem 1978, table 4-4).

<table>
<thead>
<tr>
<th>Technique chosen</th>
<th>Percentage distribution of choices</th>
</tr>
</thead>
<tbody>
<tr>
<td>More labor-intensive than LDC optimum</td>
<td>15</td>
</tr>
<tr>
<td>LDC optimum (at market prices)</td>
<td>38</td>
</tr>
<tr>
<td>Between LDC optimum (at market prices) and U.S. technology</td>
<td>32</td>
</tr>
<tr>
<td>U.S. technology or more capital-intensive</td>
<td>15</td>
</tr>
</tbody>
</table>
Although it is not possible to generalize from the findings to sectors or countries other than those from which the sample was drawn, the figures suggest that **privately** excessive capital-intensive choices are being made in a high percentage of cases; a fortiori the percentage of incorrect choices is even higher at shadow prices. A number of factors can be adduced to account for the failure to minimize private costs, but the existence of such erroneous choices suggests that issues in addition to distortions of factor prices warrant attention. 1/

SOME CHARACTERISTICS OF THE PRODUCTION PROCESS

Before proceeding to a discussion of possible qualifications to the results obtained in the foregoing section, two issues may be addressed with the available studies. The first relates to the existence of nonhomothetic production relations—that is, production in which a particular factor, such as unskilled labor, is relatively more efficient at low levels of output than at higher levels. The second relates to the specific location at which substitution is feasible in the production process—that is, in core or peripheral activities. Closely associated with the second issue is whether the choice that exists in core equipment is derived from machinery based on varying design principles or from the variance in prices of suppliers of essentially similar equipment.

Nonhomothetic Production Relations

In a conventional isoquant representation of a nonhomothetic production function, the successively higher isoquants become increasingly close

1/ Extremely interesting analyses of this question are provided by Amsalem (1978), Lecraw (1979), and Williams (1975), the third for public sector enterprises in Tanzania.
to each other near one of the axes (figure 2a). With the particular isoquant map depicted, the marginal rate of substitution decreases along a ray from the origin, and the optimal capital-labor ratio increases with the scale of output, even with constant relative factor prices. Whereas the equation describing the expansion path of a homothetic production function is $K/L = k = f(w/r)$, the equation in the nonhomothetic case becomes $k = g(w/r, Q)$.

The importance of the issue of nonhomotheticity stems from the fact that even without a rise in the wage-rental ratio, the employment-generating effects of increased output will be limited by the character of the underlying production function; indeed it is possible for employment to decline as output rises under constant relative factor prices. This adverse effect on employment growth would augment any adverse effect arising from an upward drift in the wage-rental ratio.

Because of the ease of confusing nonhomotheticity with (Hicksian) labor-saving technical progress obtained from the conventional procedures for estimating constant-elasticity-of-substitution production functions, it is important to separate the two phenomena, for they are likely to have different policy implications. If production processes exhibit nonhomotheticity, they are likely to do so only over a limited range of output \(^1\). In contrast,\(^1\)

\(^1\) In particular, a principal source of the poorer relative productivity of labor at higher output levels (in Hicks’ terms, the regressivity of labor) lies in the efficiency of mechanized peripheral operations, such as conveyors and packing machines which are not, however, economically efficient at lower scales because of their large capacity and indivisibility. For numerical examples see Pack (1976) and the studies of brewing (Keddie and Cleghorn 1975), fertilizer (Disney and Aragaw 1975), and maize milling (Uhlig and Bhat 1976). Once these activities have been largely mechanized, it may be that the production function is homothetic at still higher output levels, even if exhibiting conventional scale economies. But, at least in mechanical engineering, the study of Lamyai, Rhee, and Westphal (1978) suggests considerable nonhomotheticity over a large production range, which does not derive from the mechanization of peripheral activities.
Figure 2a. Nonhomothetic Isoquants: Continuous Case

Figure 2b. Nonhomothetic Isoquants: Noncontinuous Case
labor-saving technical progress, constantly being reinforced by new research, will continue regardless of the level of output achieved. Although one policy prescription in the second case may be the need to undertake capital-saving research, nonhomotheticity as a cause of poor employment performance may be subject to benign neglect, because it may not hold after some minimum output levels are achieved. Engineering studies are helpful in discriminating between the phenomena, given the considerable difficulties attendant on econometric discrimination between them. 1/

Because I am interested in the effect of nonhomotheticity on employment growth as output expands with constant relative factor prices, I measured the change in the capital-labor ratio for the appropriate (maximum PDV/K) techniques at successively higher scales of production. Other definitions and measurements are, of course, possible. Table 6 presents the evidence on the existence and strength of nonhomotheticity, as calculated from the data provided in the various studies surveyed. A "yes" entry in table 6 indicates that the capital-labor ratio increases significantly between the scales indicated. Thus some small increases in capital-intensity—such as that of 0.6 percent in leather processing—are viewed as being consistent with homotheticity. Three of the nine sectors indicate substantial "inferiority" of labor: brickmaking, fertilizer, and maize milling. 2/ It should be noted that nonhomotheticity does not occur uniformly across all scales: for example,

1/ For two efforts and functional forms see Christensen, Jorgensen, and Lau (1973) and Vinod (1972).

2/ Sugar processing would exhibit nonhomotheticity if the criterion of maximum PDV were used to determine the optimal technique at each scale. But at the highest scale—50,000 tons a year—a technology yielding less than a 1 percent decrease in PDV as compared with the least-cost technology exhibits the same capital-labor ratio as the least-cost technology at the lowest scale. Consequently the difference in the capital-labor ratio is ignored.
Table 6. Incidence and Effect of Nonhomothetic Production Relations, by Sector

<table>
<thead>
<tr>
<th>Sector</th>
<th>Significant nonhomotheticity found over range of production scales analyzed</th>
<th>Range of production scales over which nonhomotheticity occurs (smallest scale analyzed =1.00)</th>
<th>Percentage change in capital-labor ratio over nonhomothetic range</th>
<th>Percentage increase in average labor productivity over nonhomothetic range</th>
</tr>
</thead>
<tbody>
<tr>
<td>Shoes</td>
<td>no</td>
<td>--</td>
<td>--</td>
<td>--</td>
</tr>
<tr>
<td>Cotton weaving</td>
<td>no</td>
<td>--</td>
<td>--</td>
<td>--</td>
</tr>
<tr>
<td>Cotton spinning</td>
<td>no</td>
<td>--</td>
<td>--</td>
<td>--</td>
</tr>
<tr>
<td>Brickmaking</td>
<td>yes</td>
<td>1.00-4.00</td>
<td>306</td>
<td>95</td>
</tr>
<tr>
<td>Maize milling</td>
<td>yes</td>
<td>1.00-1.40</td>
<td>68</td>
<td>96</td>
</tr>
<tr>
<td>Sugar processing</td>
<td>no</td>
<td>--</td>
<td>--</td>
<td>--</td>
</tr>
<tr>
<td>Brewing</td>
<td>no</td>
<td>--</td>
<td>--</td>
<td>--</td>
</tr>
<tr>
<td>Leather processing</td>
<td>no</td>
<td>--</td>
<td>--</td>
<td>--</td>
</tr>
<tr>
<td>Fertilizer</td>
<td>yes</td>
<td>1.67-2.67</td>
<td>18</td>
<td>22</td>
</tr>
</tbody>
</table>

-- Not applicable.

Source: Calculations based on data in the sources listed in table 2.

a/ Interest rate equal to 10 percent.
in fertilizer production it occurs between the second and third scales considered (1,000 and 1,600 tons a day) but not between the first and second scales (600 and 1,000 tons a day). Given the assumed wage, maize milling exhibits an increase in the (least-cost) capital-labor ratio at an interest rate of 10 percent but not at 20 percent. 1/ At the higher interest rate, the switch in optimal technique from equipment made in India to European machinery does not occur.

The numerical results in table 6 indicate, despite the well-deserved attention to distortion in factor markets, that in some production sectors purely technological phenomena associated with the increasing scale of output can lead to capital-deepening and dramatic increases in the productivity of labor, even if relative factor prices are held constant. 2/ That this should be so in at least two fairly labor-intensive sectors--brickmaking and maize milling--indicates one of the difficulties facing industrial planners concerned with generating employment. 3/ On the other hand, in two-thirds of the sectors, homotheticity does hold over the range analyzed, suggesting that nonhomotheticity may not be a quantitatively significant drawback to employment creation through labor-intensive choices of technique.

1/ The dependence of nonhomotheticity upon the relative factor-price ratio at which the expansion in output takes place reflects the noncontinuous nature of the isoquants. With continuous neoclassical isoquants, nonhomotheticity occurs regardless of the relative factor prices. The process-analysis results can be seen in figure 2b, in which a change in optimal technique occurs at \( \frac{w}{r} \) but not at \( \frac{w}{r} \).

2/ Put slightly differently, strong nonneutral scale economies exist at output levels below those shown in table 2. At the scale shown there, scale economies have been exhausted.

3/ The sectors in table 6 are arranged in order of increasing capital intensity, as measured at the highest scale of production considered. Thus, despite the nonhomotheticity, both brickmaking and maize milling ultimately are labor-intensive sectors.
Core and Peripheral Substitution Possibilities

From the viewpoint of production theory and the perspective of policy, the character of core and peripheral substitution possibilities are of interest. Even the detailed process studies often have insufficiently emphasized the character of substitution possibilities and hence provided less information than was in fact used by the various authors. 1/

There is a fundamental asymmetry in significance between potential choices in peripheral and core operations. Most studies that have observed LDC factories in operation conclude that there already is extensive exploitation of the labor-using opportunities in peripheral operations: rather than purchase any machinery, from filling machines to overhead conveyors, firms simply use unaided labor. 2/ They need not obtain a considerable amount of technical information about alternatives. In contrast, differing technical options in core operations necessitate investment to obtain information about alternative designs and the varying prices among manufacturers of technically similar equipment. I will explore some of the implications of the costs of information in the next section.

Table 7 presents a summary of the types of substitution possibilities found in each industry and a measure of the quantitative importance of labor-intensive peripheral operations. In five of the nine sectors, peripheral activity affords a significant increment to the jobs that would be created by reliance on the most capital-intensive technology, though not all of the added jobs are to be found there. In three sectors—maize milling, brewing,

1/ This is not true of the Strathclyde studies.

2/ See, for examples, Pack (1976) and Ranis (1973).
Table 7. Source of Labor-Capital Substitution

<table>
<thead>
<tr>
<th>Sector</th>
<th>Percentage increase in employment from core and peripheral activities relative to employment using capital-intensive technology</th>
<th>Percentage increase in employment from peripheral activity</th>
<th>Choice of machines for the core activity</th>
<th>Major difference in design principle</th>
<th>Different countries of origin</th>
</tr>
</thead>
<tbody>
<tr>
<td>Shoes</td>
<td>--</td>
<td>--</td>
<td>yes</td>
<td>yes</td>
<td>yes</td>
</tr>
<tr>
<td>Cotton weaving</td>
<td>--</td>
<td>--</td>
<td>yes</td>
<td>yes</td>
<td>yes</td>
</tr>
<tr>
<td>Cotton spinning</td>
<td>169</td>
<td>14 (handling)</td>
<td>no</td>
<td>yes</td>
<td>yes</td>
</tr>
<tr>
<td>Brickmaking</td>
<td>217</td>
<td>25 (handling)</td>
<td>yes</td>
<td>yes</td>
<td>yes</td>
</tr>
<tr>
<td>Maize milling</td>
<td>47</td>
<td>46 (receiving, storing, &amp; packing)</td>
<td>yes</td>
<td>yes</td>
<td>yes</td>
</tr>
<tr>
<td>Sugar processing</td>
<td>--</td>
<td>--</td>
<td>yes</td>
<td>yes</td>
<td>yes</td>
</tr>
<tr>
<td>Brewing</td>
<td>23</td>
<td>18 (bottling)</td>
<td>no</td>
<td>no</td>
<td>no</td>
</tr>
<tr>
<td>Leather processing</td>
<td>--</td>
<td>--</td>
<td>yes</td>
<td>yes</td>
<td>yes</td>
</tr>
<tr>
<td>Fertilizer</td>
<td>221</td>
<td>221 (loading &amp; bagging)</td>
<td>yes</td>
<td>yes</td>
<td>yes</td>
</tr>
</tbody>
</table>

-- Indicates that peripheral activity does not afford significant efficient increases in employment.

Source: Calculations based on data in the sources listed in table 2.
and fertilizer—almost all of the additional jobs resulting from the choice of labor-intensive technology are in peripheral operations. In eight of the nine sectors, some form of choice exists within the core activity itself: in most instances that choice exists both in the design principle of particular machines and in the source of supply, the latter permitting lower prices for similar equipment. 1/

**ADDITIONAL QUESTIONS ABOUT APPROPRIATE TECHNOLOGY**

In the light of the large magnitude of benefits to be derived from a correct choice of technique, several obstacles alleged to deter the adoption of appropriate technology are best restated in a benefit-cost framework. For example, it often is asserted that adoption of labor-intensive techniques is constrained by their requirements for maintenance and skilled manpower and, if used equipment is concerned, by the unavailability of spare parts and the problems of identifying good used machines. Although the empirical foundation underlying such skepticism is rarely set out, assume that it contains some substance. Usually such an acknowledgement is transmuted into a counsel of despair: the shortages identified allegedly make it impossible for appropriate techniques to be adopted. The marginal-cost curve for production with such equipment thus is implicitly assumed to be not only high, but vertical.

An alternative approach is superior: Investment may be required to remove or reduce the alleged shortages, and the cost of the necessary outlays should be compared with the calculated benefits. If the unavailability of

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1/ An indication of the existence of choice in core equipment does not imply that every stage of production affords it or that it necessarily is quantitatively significant. For the quantitative significance see table 3.
spare parts reduces the profitability of used equipment, facilities could 
be established to produce them; if older equipment does require more skilled 
labor, additional training programs or subsidies might be instituted. Only 
a thorough comparison of the costs and benefits of such programs allows an 
evaluation of the economic rationality of the labor-intensive path of indus-
trial development. I turn now to an examination of the constraints most 
often mentioned as obstacles to this strategy: the requirements for skilled 
manpower; the low levels of factor efficiency and capacity use; the effects 
of technical change; the problems associated with used equipment; and the 
high costs of technical information.

Skill Requirements

Most of the studies surveyed—the Strathclyde studies are 
exceptions—mention requirements of skilled labor only in passing. In part 
this treatment reflects the observation of production activities that could 
not exist if the scarcity of skilled labor were a constraint. For example, 
the study of can making by Cooper and others (1975) describes a number of 
production methods in use. In East Africa they found that "supervision costs 
per unit are lowest with 'intermediate' (vintage) technologies, but rise with 
greater labor and capital intensity" (p. 111). 1/ In Thailand they found 
that supervision costs were generally about 15 to 20 percent of total unit 
costs, but there was no particular pattern to be observed among substantially 
different machines. Perhaps the following comment is most relevant: "There

1/ Amsalem (1978), in his thorough study of textile and pulp production, 
also found that skill levels rise toward both ends of the technology 
spectrum: the more labor-intensive processes require skilled operatives; 
sophisticated equipment requires highly trained repairmen.
are also some obvious differences between the type of supervision needed on automated lines—generally people with a high level of technical ability to manage machines—and the type needed to organize a large number of workers on a labor-intensive line. Probably the skills needed for organizing workers... are more readily available in developing countries than those needed for automated lines" (p. 112).

For six of the nine detailed industry studies used in calculating potential income gains, it is possible to calculate either the skill distribution of the labor force or the average wage level for the alternative techniques considered. Table 8 presents these data. Of the four sectors in which the skill distribution can be calculated, two reveal a higher ratio of skilled workers to total labor force for the appropriate technique; in one of the four sectors for which the average wage is calculated, it is higher for the appropriate technique. 1/ Nevertheless even lower skill intensities in the appropriate technology may require a larger absolute number of skilled workers, given their greater total employment. These absolute differences are shown in table 8. Given those differences, critics who are skeptical of the feasibility of labor-intensive technology might well feel vindicated: even in such sectors as brickmaking, in which the skill intensity per project is lower with the least-cost technique, the aggregate skill requirement is greater. That requirement reflects both the larger total employment per project and the larger total number of such projects that can be undertaken given their lower capital-output ratio. The relevant analysis remains to be done, however:

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1/ The average wage reflects the calculated labor requirements of the synthetic technology weighted by the observed wage differences in typical poorer LDCs. I continue to work with market prices rather than shadow prices.
Table 8. Skill and Wage Differences between Processes, by Sector

<table>
<thead>
<tr>
<th>Sector</th>
<th>Percentage of skilled workers</th>
<th>Absolute difference in number of skilled workers required per $100 million of investment (appropriate minus capital-intensive)</th>
<th>Relative wage in capital-intensive process (appropriate = 100)</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>Appropriate</td>
<td>Capital-intensive</td>
<td></td>
</tr>
<tr>
<td>Shoes</td>
<td>58  a/</td>
<td>55  a/</td>
<td>5,744</td>
</tr>
<tr>
<td>Cotton weaving</td>
<td>n.a.</td>
<td>n.a.</td>
<td>n.a.</td>
</tr>
<tr>
<td>Cotton spinning</td>
<td>n.a.</td>
<td>n.a.</td>
<td>n.a.</td>
</tr>
<tr>
<td>Brickmaking</td>
<td>2</td>
<td>7</td>
<td>445</td>
</tr>
<tr>
<td>Maize milling</td>
<td>9</td>
<td>13</td>
<td>746</td>
</tr>
<tr>
<td>Sugar processing</td>
<td>n.a.</td>
<td>n.a.</td>
<td>n.a.</td>
</tr>
<tr>
<td>Brewing</td>
<td>n.a.</td>
<td>n.a.</td>
<td>n.a.</td>
</tr>
<tr>
<td>Leather processing</td>
<td>42</td>
<td>26</td>
<td>1,464</td>
</tr>
<tr>
<td>Fertilizer</td>
<td>n.a.</td>
<td>n.a.</td>
<td>n.a.</td>
</tr>
</tbody>
</table>

n.a.  Not available.

Source: Calculations based on data in the sources listed in table 2.

a/ Average of plants in Ghana and Ethiopia.

b/ Different skill levels weighted by U.K. skill differentials.
that is, the calculation of the cost of obtaining the additional skills and the comparison with the benefits to be obtained from the choice of least-cost technology thus made possible. 1/

Assume that the observed annual wage difference between skilled and unskilled labor is $\Delta w$ and that to obtain this difference a currently skilled worker had invested $G$, including such explicit costs as tuition and such implicit costs as income forgone during formal education or on-the-job training. Each skilled worker would then have invested up to the point:

$$G = \Delta w A_{in},$$

where $A_{in}$ is the present value of an annuity of $1$ for $n$ years at an interest rate of $i$ and where $n$ is the anticipated work life after training. $G$ can be thought of as the amount of investment in upgrading skills that would now have to be spent by a firm on each currently unskilled worker to obtain the requisite skills to produce with an appropriate technology. $(S_b - S_a)G$ is then the total difference in educational investment per sector necessary to produce with the appropriate (maximum PDV/K) technique as compared with the capital-intensive technique, where $S_a$ and $S_b$ are the total number of skilled workers required by the two techniques per $\$100$ million of investment. If skilled labor were the sole constraint, the benefit-cost ratio to the firm of such investment would be:

$$\frac{B}{C} = \frac{\Delta Y}{(S_b - S_a)G},$$

1/ Here I follow Becker (1964).
where $\Delta Y$, as defined in equation 1, is the present discounted value of the additional nonwage income obtained from the choice of the appropriate technique. 1/

Such calculations have been made for leather processing and shoe manufacturing, the two sectors showing the largest absolute increases in skill requirements. It is assumed that the interest cost of training funds in the past had been either 10 or 20 percent and that workers anticipated a working life after completion of training of forty years. The value of $\Delta Y$ is calculated from table 3, which presents annual income gains, by using an interest rate of 10 percent for the expected life of the project. The benefit-cost ratios so calculated are shown in table 9. Under the conservative assumption that workers have been able to borrow at 10 percent, which would lead to a higher $G$ for a given $\Delta w$, the benefit-cost ratios are 35 in shoe manufacturing and 63 in leather processing. These are the ratios that prospective investors could anticipate from expenditure on the skills necessary to implement appropriate technology. Given the usual difficulty

Table 9. Benefit-Cost Ratios from Investment in Upgrading Skills

<table>
<thead>
<tr>
<th>Sector</th>
<th>Assumed borrowing rate of skilled workers</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>10 percent</td>
</tr>
<tr>
<td>Shoe manufacturing</td>
<td>35</td>
</tr>
<tr>
<td>Leather processing</td>
<td>63</td>
</tr>
</tbody>
</table>

1/ The numerator excludes additional labor income because such calculations usually assume full employment. Additional labor income from the correct choice of technique is thus offset by reduced income elsewhere in the economy.
in edging benefit-cost ratios above unity, these numbers, though rough orders of magnitude, are remarkably high. They suggest that those who believe skill constraints to be the principal factor limiting the adoption of labor-intensive technologies might consider advocating a bundling of the requisite education and investment funds rather than urging a resort to capital-intensive technologies. Although the specific numerical results will depend on skill differences, appropriate interest rates, and the partial elasticities of substitution among various factors, it is clear that the issues associated with skill requirements should be considered within a benefit-cost framework.

**Factor Efficiency and Capacity Use**

The studies relied upon to obtain the numerical results use data generated by current operations in LDC plants; pure technical engineering relations between inputs and outputs are leavened by the operating efficiency in existing factories. Thus the factor substitution possibilities shown in the various studies do not constitute pure engineering isoquants in the sense of being physically achievable norms as defined by equipment producers. The incorporation of operating inefficiency into the data may mask the profitability of appropriate, as compared with capital-intensive, technologies. Consider the simplified two-period present discounted value formula:

\[
\text{PDV} = -K + \frac{(R-wN)}{(1+r)} + \frac{(R-wN)}{(1+r)^2},
\]

where \( K \) is the initial total investment, \( R \) the total revenue \((PxQ)\), \( w \) the average wage rate, and \( N \) the input of labor. The evidence from the various studies indicates that the realized capital-output ratio per hour of plant operation is, for all technologies, relatively close to the standards to be expected on the basis of experience in the advanced countries,
whereas the labor-output ratios are much higher. Thus, in calculating PDV, both K and R are typically unaffected by productive inefficiency, which is entirely reflected in additional labor requirements. The PDV of the appropriate technique, b, will be reduced more than that of the capital-intensive one, a, because \( N_b \) is greater than \( N_a \).

An appropriate technology may currently exhibit a lower PDV, even though it would exhibit a higher PDV than a more capital-intensive technology if improved (achievable) levels of efficiency were realized. The potential benefits obtainable from the choice of appropriate technology may thus be understated in my earlier calculations. Just as a package of investment in skill formation and appropriate equipment choice may be privately profitable, a combination of management consulting or extension services with the appropriate technology may also provide desirable. 1/ Any such additional benefits would be gross; to arrive at the net benefit would require subtracting the costs necessary to realize the higher productivity level.

The perhaps-too-pessimistic estimate of efficient substitution possibilities obtained by ignoring potentially remediable inefficiency of one type is further reinforced by the handling of the question of capacity use in most of the studies. A plant is assumed to work two or three shifts in the standard calculation, though this does not accurately characterize operating plants. Although some assumption is necessary to undertake the calculation, this one conflicts with observed rates of capacity use in most LDCs, even if it were valid for some countries in which data were gathered. Lower rates—whether attributable to fluctuations in foreign exchange and imported raw materials or to electricity failures, shortages of domestically produced inputs, or a cost-minimizing ex ante decision (Winston 1974)—will

1/ Many World Bank industrial loans already include a component designed to raise productivity.
reduce the profitability of the capital-intensive technique relative to the labor-intensive technique. 1/ Allowing for systematic underuse would thus be likely to increase the PDV of some of the labor-intensive techniques not currently optimal at tested factor prices. For example, a decline from full to two-thirds utilization reduces the PDV in leather processing by 62 percent for the appropriate (maximum PDV/K) technology, but by 79 percent for a capital-intensive, turnkey plant.

The effect of a reduction in labor productivity below that observed in "standard" LDC plants is less clear. For any given level of labor inefficiency, the percentage increase in labor costs will be considerably greater with the labor-intensive techniques because there is little labor which can be inefficient in the mechanized techniques. Thus in two subprocesses in brick-making—clay preparation and brickforming—the most mechanized techniques do not experience any increase in labor costs when labor productivity is assumed to be half its "normal" level, whereas the appropriate technique sustains a doubling of labor cost. Nevertheless the present discounted value of production costs of the appropriate technique in these subprocesses, even with labor inefficiency, is only 20 percent of that of the capital-intensive technique. 2/

Although the continued labor cost in the presence of low productivity depends on the particular processes and can in no sense be generalized, it

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1/ This conclusion follows most directly if it is assumed that the life of equipment is invariant with respect to the intensity of use of equipment. In such a case the addition to annual capital costs would be greater for the more capital-intensive process. If machines do not become obsolete, so that length of life varies with the rate of use, it still is likely to be true that the present discounted value of the fairly distant profit flows would not compensate for the additional initial capital costs of the capital-intensive equipment.

2/ The 20-percent figure refers to total production costs rather than the value-added component because some small changes also occur in nonprimary costs.
emphasizes the fact that statements about the effects of potential inefficiency cannot be based on a priori judgments, but must be examined in careful case studies.

A difference in the implications of potential excess capacity and those of low labor productivity for choice of technique is worth noting. Excess capacity is not likely to be affected by any specific microeconomic policies because it often reflects such macroeconomic phenomena as balance-of-payments shortages and the ensuing rationing of foreign exchange. In contrast, low productivity can be redressed, at least in part, by such policies as technical aid and training services. But it, too, is undoubtedly affected by such macroeconomic policies as those promoting import substitution. Thus, if a labor-intensive technology were to become optimal with some improvement in productivity, the cost of achieving this increase--say, through extension services--would have to be compared with the benefits accruing from the correct choice of technique. More generally, there is no knowledge about the different levels of productivity associated with varying techniques for the same process, but the effect of such variation on output and on optimal technique probably is substantial.

Effects of Technical Change

Most of the microeconomic studies surveyed have perforce assumed no technical change. It is difficult enough to establish current production options without trying to forecast future changes in technology or ascertaining past trends. The effect of this omission is ambiguous. It is clear that much of the research and development oriented to production is designed to increase the efficiency of techniques used in the countries undertaking that research and development. If there were pure efficiency gains--that is, if the inputs of capital and labor were reduced for each unit of output--the
choices faced by an LDC undertaking investment would become increasingly circumscribed in relation to those presented in table 2. Because of research restricted to capital-intensive techniques, the more capital-intensive techniques might eventually yield greater profitability at any given wage-rental ratio.

The evidence in at least one industry—-weaving—indicates that new equipment has primarily reduced labor requirements, but substantially increased the cost of a new loom. In this process, at least, research on improving production has not led to equipment that dictates the disregard of older methods of production in the LDCs. Indeed the newer equipment is (privately) profitable only at wages considerably higher than market wages even in the richer Latin American countries. Without considerably more microeconomic evidence, it is not possible to know which of the two types of result—general factor saving or labor saving at the cost of more expensive equipment—would occur from research on capital goods in developed countries. Nevertheless the fact that such a large range of choice now is extant, after more than a century of technical progress, provides some ground for optimism.

Most completed research has not systematically explored the additional elements of choice that equipment produced in the LDCs affords, but in certain of the studies examined here, some of the choice derives from LDC production. Recent work by Rhee and Westphal (1977) and another World Bank study (1975) indicate that LDC-produced equipment may substantially expand the set of efficient choices. The preliminary results of a study of Argentine capital-goods production indicate the same. 1/

1/ A survey of a number of issues related to existing LDC capital-goods production is provided in Pack (1979b).
Problems Associated with Used Equipment

As noted earlier, the adoption of used equipment may introduce additional choice, but it invariably raises questions because of doubts about the availability of spare parts and the dangers of obtaining lemons.

Although there is frequent reference, primarily anecdotal, to shortages of spare parts, it often is overlooked that firms in many countries have bought a considerable amount of equipment in used condition. If shortages of spare parts impeded production, there would be only limited manufacturing activity and virtually no efficient plants. Many companies set up their own machine shops, which can produce a wide variety of parts; many LDCs with a long industrial history have numerous independent workshops capable of producing spares. If that capacity already is present, upgrading alone may be necessary. Often this upgrading may require only the elimination of such discriminatory policies as quantitative restrictions on metals or on machine tools of particular quality. Such restrictions undoubtedly work more strongly against the smaller shops, which are likely to be effective in producing spares, because they have less ability to deal with the government agencies.

If some specific skills are absent, but the base of ability is broad, expenditure on extension services could overcome bottlenecks. Again the desirability of such outlays should be viewed within a general cost-benefit calculus. Skill or employment shortages may simply require investment in training or plant. Given the magnitude of potential benefits, large outlays could be justified. This option may not be open in countries having little demonstrated ability upon which to build. For such countries, it is not clear that investment in training is likely to pay off. Consequently the problems associated with spare parts could become critical. But this line
of reasoning suggests that arguments underlying a blanket dismissal of the feasibility of using used equipment have, until now, been insufficiently finely honed. In many countries an existing small-scale capacity to produce spare parts, augmented by some expenditure on extension services, may be all that is required; countries lacking such a capacity may face even more fundamental problems in which the issue of factor substitution is of secondary importance.

One remaining issue, recently emphasized by Cooper and Kaplinsky (1975), is the difficulty of ensuring that used equipment performs well after it has been disassembled, shipped, and reinstalled in a new climate: reliability is likely to be higher with new machines, given the guarantees and technical aid provided by equipment producers. The performance of equipment in production may well be the fundamental uncertainty in the calculation of a firm. Nevertheless, whereas any one firm might purchase a "lemon," the probability for all transactions is much lower if many firms buy used equipment and if independent probabilities are assumed for each such purchase. Indeed the Cooper-Kaplinsky sample included many high-productivity used machines. Thus, if lemons were the only reasons to expect different productivity, some insurance mechanism could eliminate the risk. But in the absence of such a mechanism, firms would surely take account of this risk in their calculation, though the effect of this element could be attenuated if a number of purchases were planned.

Costs of Information

I now turn to a set of issues that typically have not been raised. All of the studies demonstrating the availability of a range of methods have required great effort: the Strathclyde studies involved at least one
economist and one engineer working together for a year or more; the study from which the data on substitution possibilities in textiles were taken was carried out by a large consulting firm with extensive experience in the cotton-textile industry. The obvious questions are these: Does the typical owner-manager in an LDC have the information sources at his disposal to enable him to identify existing substitution possibilities? Or are those possibilities difficult to learn about? Although it is easy to become informed about one segment of the isoquant if manufacturers' representatives are accessible, it is difficult for other segments. Do the can producers in East Africa know about the techniques used in Thailand? Or could they obtain such knowledge fairly easily? If they cannot, some fundamental questions are raised. In particular, many of the studies surveyed demonstrate that the choice of technique may have only a minor effect on profits: improved inventory management, reduced material wastage, better training of employees, and so on may yield greater increases in profits than choosing the appropriate technique rather than the capital-intensive technique. These search costs are in addition to such explicit costs as those for traveling to trade fairs or hiring consultants.

Traditional analysts emphasizing profit maximization would suggest that firms will try to realize even marginal profit gains; others would argue that "satisficing" behavior is more relevant because some profits will be traded for greater leisure, a less hectic life, and so on. But even within the paradigm of profit maximization, the choice of technique may be subordinated simply because alternative uses of the businessman's time are more profitable than carefully searching for the optimal technique. Once the
scarcity of both entrepreneurial and staff time (in larger firms) is taken into account, many activities warrant the allocation of time because of the contribution to profitability: inventory control, floor supervision, finding lower cost suppliers, identifying new markets, coaxing government to provide higher protection, securing rebates on tariffs on inputs, exploiting the entire panoply of government measures—all these may be more profitable uses of time than choosing a technique, even though that choice could also improve profits. Even limiting the discussion to those activities which are not simply rent-generating and focusing on productivity, it is of interest to compare the potential gains calculated in table 3 and attributed to correct choice of technique with gains obtainable from inefficient firms moving toward the production frontier of the industry, regardless of the technique they employ. Farrell (1957) has termed these the gains from price efficiency and technical efficiency.

Two studies—Meller (1976) and Pack (1974)—provide some rough orders of magnitude of the gains from technical efficiency. 2/ Meller

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1/ With respect to inventory control the importance of working capital in some industries may be seen in the following: "securing a low working capital requirement exercises a very much greater effect [on profits] than switching from one source of equipment to another, or by adopting one form of machine or labor intensity in preference to another ..." (Uhlig and Bhat 1976, pp. 161-62). Thus a firm just beginning production might correctly spend its time on choosing an appropriate location rather than on a detailed analysis of alternative equipment; existing firms might attempt to secure transport of raw materials so that low inventories can be maintained along with an assured supply of raw materials. Similarly, in brewing beer, large cost savings can be achieved by "shortening the storage period, in stainless steel vessels, from 28 to 10 days" by altering the storage place of the vessels (Keddie and Cleghorn 1975, p. 54). These examples are not meant to suggest that economizing on working capital is, in all industries, likely to exert such great effects. Instead, they are to emphasize the range of entrepreneurial activities that can yield substantial increases in profits.

2/ For a more recent study see Page (1978).
found that about 75 percent of Chilean companies in each of the fourteen industries he examined are less than half as efficient as those on the production frontier. Thus a majority of firms in each industry has the potential to double output. Similarly I have calculated that moving to the production frontier could yield output increases in India ranging from 41 percent in bicycles to 270 percent in paint production. These sets of estimates are consistent with realized productivity gains obtained by various technical aid missions, summarized by Liebenstein (1966), and with recent estimates by Katz (1977) of the improvement in productivity in individual plants in Argentina. In addition, myriad studies of effective protection imply substantial productive inefficiency, though the dispersion of firms within sectors is not explicitly addressed.

Even if only half the existing inefficiency were eliminated, the added profits would, in many cases, be of the same order of magnitude as those shown in table 3 to accrue from a search for the optimal technique. 1/ Once the costs of searching are recognized, particularly the forgone profit from alternative activities, I would expect, other things being equal, that the choice of appropriate equipment is more likely in two situations: one in which the cost required to obtain such information is lowered; one in which the effort is likely to be perceived as having a fairly high or

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1/ Despite a similarity in aggregate output gain, there may be different distributional implications if the gains from improving productivity mainly accrue as higher profits or wages to those currently employed, not as income to new employees.
certain potential payoff. Although it is difficult to establish the magnitude of search costs empirically, two types of evidence are suggestive: the adoption of equipment manufactured by local firms in LDCs; the behavior of multinational corporations with respect to technical choice.

Rhee and Westphal (1977) found that Korean textile producers use quite labor-intensive looms that are domestically produced. The existence of local producers of equipment surely acts to reduce search costs. The salesmen can provide great detail on production characteristics; the plant producing

1/ Say that the profits of a business depend on the level at which each of three activities is set—production management ($A_1$), marketing ($A_2$), and government lobbying ($A_3$). The profit function then is $\pi = \pi(A_1, A_2, A_3)$. The owner, or the owner's staff, has the following time constraint: $T_1 + T_2 + T_3 = T$, where $T$ represents their total working hours. Profits then are a function of the allocation of time to each activity: $\pi = \pi[A_1(T_1), A_2(T_2), A_3(T_3)]$. Solution of the Lagrangian maximization yields the following condition for the optimum:

$$\left(\frac{\partial \pi}{\partial A_1}\right) \left(\frac{\partial A_1}{\partial T_1}\right) = \left(\frac{\partial \pi}{\partial A_2}\right) \left(\frac{\partial A_2}{\partial T_2}\right) = \left(\frac{\partial \pi}{\partial A_3}\right) \left(\frac{\partial A_3}{\partial T_3}\right).$$

The first part of each expression corresponds to the potential payoff; $\partial A_1 / \partial T_1$ indicates the effort required to obtain information. Introducing explicit outlays on information, such as consultant's fees, would require a second constraint—$C_1 + C_2 + C_3 = C$, where $C$ represents total explicit outlays and yield additional equalities:

$$\left(\frac{\partial \pi}{\partial A_1}\right) \left(\frac{\partial A_1}{\partial C_1}\right) = \left(\frac{\partial \pi}{\partial A_1}\right) \left(\frac{\partial A_1}{\partial T_1}\right).$$

An alternative approach that could account for the limited search for appropriate techniques is suggested by Nelson and Winter (1975). Numerical simulation of the behavior they posit for the decision rules of firms generates results that closely conform to those of time series for such advanced countries as the United States.
equipment can be visited at little cost; the product can be examined for quality. But in the absence of local producers and their salesmen, equipment buyers must rely on catalogs and sales representatives of foreign companies. Those representatives provide the easiest access to information on relevant equipment, but the attempt to assemble a comprehensive set of literature about the answers to relevant technical questions is no mean feat. Many producers may not be known. Moreover catalogs, unlike salesmen, cannot answer questions about responses to idiosyncratic circumstances; nor can they easily indicate how a new piece of equipment will mesh with equipment already in place. Thus the presence of local producers reduces the search time, the explicit travel costs, and probably the degree of uncertainty attached to whether the equipment will perform according to catalog specifications. In contrast with South Korea, other countries exhibiting a configuration of factor prices even more favorable to the adoption of semiautomatic looms—or at least conventional rather than shuttleless looms—often have not adopted them. There is reason to believe that the costs of information explain much of this cost-increasing decision. 1/

The second type of evidence consistent with the importance of information costs is reported in a number of studies of the factor proportions used by multinational corporations (MNCs) locating in LDCs. Studies relying on plant visits have often found that MNCs use techniques that are more labor-intensive than those of local companies producing the same product; 1/

Of course, there are fascinating questions about the failure of LDC capital-goods producers to pursue marketing in other LDCs, despite the attractiveness of their products. This pattern may be changing. See Cortes (1978).
studies based on statistical evidence have uncovered no systematic differences between MNCs and local companies. Indeed, as often as not, the operations of MNCs are more labor-intensive. 1/ These findings are surprising because MNCs typically pay higher wages, can borrow at lower interest rates either in the host country or internationally, and often are the beneficiaries of tax provisions denied to local companies, such as accelerated depreciation and exemption from excise taxes and tariffs on imported equipment.

Several related factors are likely to be involved in explaining, despite these differences in factor prices, why MNCs typically are not more capital-intensive than local companies. First, they can easily identify and transfer equipment among subsidiaries, especially equipment that in countries having higher wages has become too expensive to use because of its labor intensity. Indeed that parent company may have established a new plant partly to use such equipment in the production of exports. 2/ Alternatively the local manager may ask the purchasing office of the parent company for advice on the purchase of used equipment if it is not available within the country. In the light of the difficulties of identifying reliable equipment, such low-cost aid to the local manager, in both time and explicit costs, clearly increases the likelihood of his employing appropriate equipment to take advantage of the factor prices he faces. Not only can a central purchasing office identify and physically evaluate the condition of the equipment; it

1/ Careful statistical studies have been carried out by Forsyth and Solomon (1977) in Ghana and Lecraw (1977) in Thailand. A survey of the literature can be found in Pack (1979b).

2/ Wells (1977) finds this to be true of MNCs based in Hong Kong. They have sought out countries having lower wages to use equipment that has lost its cost edge as a result of rising wages in Hong Kong.
probably can also obtain a better price, insofar as most studies of the market for used equipment indicate that price-setting in this market is better viewed as a bilateral monopoly rather than perfectly competitive.

POLICY IMPLICATIONS

Before considering questions of policy, I should like to summarize the principal arguments of the preceding sections.

It is evident from a number of careful empirical studies that the substitution of labor for capital is possible in large-scale manufacturing. This substitution is privately efficient at market prices in the poorer countries, such as in Sub-Saharan Africa and Southeast and Southern Asia, and could generate large gains in profits, employment, and wage income. Although I have not described the details of the technical choices available, a reading of the underlying engineering studies should demonstrate that these exist and are neither the result of wishful thinking nor a statement of the religious principles of the "small is beautiful" cult. 1/

Firms planning new investment need not choose capital-intensive techniques. But rational firm behavior and the absence of institutions to alter the costs of decision in the correct direction may lead to such a choice. Businesses that could fill the gaps in knowledge and supply the appropriate equipment are largely absent: domestic capital-goods producers, agents of used-equipment dealers, and representatives of producers of appropriate capital goods in developed countries. Given the explicit search costs

1/ To have described the characteristics of technical choices would have burdened this paper with too much detail. I nevertheless intend to provide such descriptions in a forthcoming paper.
and the alternative uses of an entrepreneur's time in other profit-augmenting activities, institutions that do reduce search costs are more likely to get a hearing. These institutions may have a capital-intensive bias: development finance corporations, international agencies, and capital-goods producers in the developed countries and their agents in the LDCs. Although the internal information networks of MNCs operate in the opposite direction, there are fewer corresponding networks for domestic companies.

What, then, are the implications for policy?

If LDC capital-goods production were encouraged, leading to plant equipment that was appropriate to LDC factor proportions, the difficulty of information dissemination would be at least partly overcome because such producers would find their markets in the LDCs. Just as salesmen from developing countries now are prominent sources of information, LDC salesmen could present the case for their equipment, which presumably is more privately profitable. Because equipment production is unlikely to be economic in more than a handful of countries, it will be necessary to encourage trade between LDCs. Although the best long-run solution may be to rely on the augmentation of existing capacity and the strengthening of current producers, aid-giving agencies can encourage greater inter-LDC trade in the shorter run by establishing wider networks for the provision of equipment on internationally financed aid projects. These networks could be fostered by broader advertising of prospective industrial projects and by employing consulting engineering firms from LDCs. The steps are necessary in any case, insofar as most consultants exhibit a fairly localized knowledge of equipment sources: Western European firms typically are unaware of equipment produced in LDCs or even in Japan.
Indeed there may be an argument for parallel feasibility studies--by a firm from a developed country and by another from an LDC--and for providing both firms with incentives to broaden their search and make some rough checks on each other.

Greater use of equipment produced in LDCs or, indeed, of appropriate equipment produced in developed countries will not solve all the obstacles of information dissemination which firms confront. But it can have two effects. First, it would lend credibility to the techniques. Agencies concerned with repayment are not, after all, academics assured of their salaries regardless of the consequences. Second, it may stimulate LDC producers to become interested in exports. Despite their excess capacity and marketable products, they typically have not been so interested. Part of this inertia appears to be attributable to the large costs of setting up organizations to market exports, part to the perceived uncertainty of results. Adequate advertising of imminent contracts reduces the initial need to set up marketing organizations. Some such advertising already exists, but it may not be sufficiently honed. Although the ministry of industry in a given country may receive that advertising, there may be considerable slippage between the ministry and local companies. Inquiries sent directly to local companies are likely to yield better results.

Before turning to broader opportunities for overcoming the obstacles associated with information, it is worth noting at least one other device for improving the flow of appropriate technology. One source of technical choice arises from the potential use of used equipment, yet it is likely that a principal source of reluctance about its use is the difficulty of ensuring
high performance after equipment is reinstalled in a new setting. If it is assumed that the aversion of LDC governments to used equipment can be overcome, an insurance mechanism could be established to encourage the adoption of such equipment. Firms purchasing used equipment could apply for some reimbursement if a specified level of productivity were not achieved. 1/

The details of such an insurance program would have to be worked out to preclude false claims, not all of which are likely to be screened out. Because legitimate claims for reimbursement would often entail outlays of foreign exchange, the insurance in individual countries might be partly financed by external funds. Offsetting the difficulties in devising and implementing such a fund are two benefits: the first is simply the direct effect on the capital-labor ratio; the second is the longer term effect of focusing on alternatives to newer, expensive equipment. If the early adopters of used equipment exhibit lower costs, they will be able to reduce prices or obtain higher profits. Either result—the market structure, including tariffs, would determine which one obtains—will generate further interest in both used and more appropriate equipment.

Although encouraging trade in capital goods between LDCs and searching for appropriate technology in internationally funded projects should encourage the diffusion of correct technology, these policies initially are likely to be more important for the larger manufacturers in LDCs. It can be argued that larger firms exhibit the greatest discrepancies between

1/ An insurance system is more desirable than special tax preferences for used equipment. Higher investment credits or more rapidly accelerated depreciation allowances, while increasing the profitability of used equipment in relation to new equipment, would simultaneously reduce the price of used equipment in relation to labor and would thus have undesirable substitution effects.
appropriate and current factor proportions, but medium-sized producers probably are more mechanized than they need be. This pattern, along with the evidence of considerable x-inefficiency, suggests that industrial extension services are necessary. To my knowledge, such services currently are not available in any LDC in a form similar to that of agricultural extension services. Some research institutes perform trouble-shooting operations, but periodically visiting plants, helping with choice of equipment, and solving production problems simply are not on their agenda. Yet in agriculture such efforts are known to have high yields. Indeed many of the benefits of technical developments cannot be appropriated without considerable local effort. The evidence surveyed in this paper, particularly the gains from the correct choice of technique, suggests that similarly high payoffs could be obtained in the industrial sector by reducing information costs to firms about alternative techniques and by reducing operating inefficiency.


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