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THE EMPLOYMENT-OUTPUT TRADE-OFF IN LDC'S--
A MICROECONOMIC APPROACH

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Abstract

This paper analyzes the possibilities for substituting labor for equipment in the production process. The data used are firm level observations in a number of less developed and semi-developed countries. This study differs from most analyses of substitution possibilities insofar as only efficient production points are considered. The results indicate much higher substitution possibilities than have usually been found. The implications of these findings for development policy are considered.

The Employment-Output Trade-off in LDC's--
A Microeconomic Approach

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A recurring question in the analysis of unemployment in underdeveloped countries is whether labor can be substituted for capital in industrial production processes. Much of the literature has been theoretical and only in the last few years have attempts been made to test alternative hypotheses empirically. Much of the development literature suggests that substitution is quite difficult, if not impossible. Modern, capital intensive processes are assumed to "dominate" (use both less labor and capital per unit of output) labor intensive processes. (9, Chap. 10) According to this view, new firms or firms wanting to expand production, insofar as they have a choice at all, will always opt for the most modern plant.

Unfortunately, the voluminous literature on production functions in developed countries, using either cross section or time series data, is of limited value in shedding light on the subject. The usual time series studies which involve estimates of the rate of disembodied technical progress along with the parameters of the production function do not discriminate between vintages of capital. Vintage models which do provide an estimate of the rate of capital augmentation do not provide simultaneous estimates of changes in labor requirements.[1] Cross section studies of the constant elasticity of substitution function might be capable of providing further evidence as poor countries might use equipment no longer profitable in advanced countries because of high wage rates. The critical parameter in deciding whether more

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*Christopher Clague provided very helpful comments on an earlier draft. I am responsible for any remaining flaws.

[1]Moreover, the estimated rates of embodiment are open to serious question. See, Berglas (3) and Jorgenson (10).

modern processes are dominant is the efficiency parameter γ . However, there are few estimates of this parameter and those which exist are open to considerable skepticism as the estimate of capital that they use, and which is a primary requirement, seems to be quite arbitrary.[1] Moreover, the estimation of the efficiency parameter requires the use of the previously estimated elasticity of substitution. As Nelson (15) has recently shown, this parameter, when estimated from cross country data may be more a distribution parameter than a production parameter, thus casting doubt on the meaning of the efficiency parameter even when it is estimated. Finally, even if reliable estimates of γ could be obtained, its interpretation is problematic as lower efficiency in LDC's (in a given industry) would not necessarily imply technical inferiority of older equipment. Rather, such differential efficiency could result from organizational or motivational factors that are unrelated to equipment characteristics.

While I do not believe that proponents of the dominance assumption have explicitly indicated the reasons for rejecting the existing empirical evidence on the possibility of factor substitution, their position could be supported by the arguments of the last paragraph.

A recently published body of data permits an alternative approach to the question of the feasibility of capital-labor substitution. The information collected by the U.N. (16) provides data on individual firms in a number of countries (France, India, Japan, Israel and Yugoslavia). Of particular note is the attempt to provide estimates of capital at replacement cost as well as a host of special characteristics which are of interest in analyzing the nature of substitution possibilities.

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[1]The most recent attempt to estimate the parameter is to be found in Daniels (5). The original Arrow et al article has a more thorough analysis of U.S.-Jananese efficiency differences (2).

We first consider the "estimation" procedure and then present the "estimated" elasticity of substitution along with other characteristics of the production process which are of interest. Unfortunately, the number of observations precludes the use of formal statistical techniques. More generally, the relatively small samples involved suggest caution before reaching strong policy conclusions. However, I interpret the evidence as being more than adequate to warrant considerable skepticism about the usual assertion of the inevitable superiority of capital intensive processes.

I. Isoquants

The basic approach is to construct a unit isoquant from the data for the firms in the sample. This was done by calculating the labor-output and capital-output ratios for each firm and plotting these. The labor measure used was total manhours involved in direct production, i.e., exclusive of management and office personnel. Capital was the dollar amount of equipment valued at 1964 replacement cost estimates. Local costs were converted to dollars at the existing official exchange rate. Buildings were omitted from the capital estimate because of the difficulties involved in comparing these across countries. I do not view this as a serious omission as most of the interest lies in labor-equipment substitution. Although labor and buildings may be substitutes as when a building may be specifically designed to minimize the amount of labor needed for the internal movement of materials, such substitution is likely to be relatively unimportant.

As is well known, the way capital is measured in such studies raises problems.[1] Ideally, one would use a measure of capital services which

[1]See Kurz and Manne (11), Lave (12) and Furobotn (8).

allowed for differential physical efficiency of various machines. Variations in the intensity of utilization such as the speed at which the equipment is operated and the duration of use would also be reflected in this measure. But given the difficulties of constructing such a measure, one is forced to rely on capital stock at replacement cost. But this is not as serious a deficiency as might first appear as our results are not particularly sensitive to small errors in the measurement of capital.

In examining the scatter of points yielded by this procedure, it was evident that in all industries a number of observations were inefficient in the sense that some other points use both less labor and capital per unit of output. This was particularly noticeable in the Yugoslav plants. One explanation could be technical inefficiency, i.e., these may be points on the efficiency frontier of a particular firm, given the equipment which they are using. Alternatively, the dominated points may result not from technical inefficiency of equipment, but from poor management or an inadequately motivated labor force. In the absence of engineering data, we assume that the dominating points constitute an efficiency frontier in the sense that, given existing techniques, some combination of such points will permit lower cost production than any dominated point, i.e. there is no "x" inefficiency associated with such points (13).

Only in the case of wheat milling where a single product is produced could output be measured in physical units, in this case in tons; in other branches which produce a number of products, output was measured as domestic value added. While this practice is usual (2), there are a number of problems. Either input or output prices may not be the same in the countries in our sample; even if the goods are internationally traded, the presence of tariffs on inputs and outputs may distort the level of domestic value added. Moreover,

differences in the price of nontraded inputs such as electricity may also affect the value added measure. Without complete input vectors and their prices, comparable measures of value added could not be obtained. However, price comparisons of a number of final products in each industry were made. Where necessary VA was adjusted in light of these comparisons to arrive at some more comparable measure of value added. However, the results using both unadjusted and adjusted value added were quite similar. Since we are using frontier points only, remaining errors will have no effect unless they result in a change in the points which are on the frontier. Thus, if "true" value added at comparable prices is understated by 50 percent for Indian firms, both the capital-output and labor-output ratios would be halved and the new point might be more efficient than some previous frontier point. In general, though, the errors would have to be even larger than 50 percent as the dominated points were usually less than half as efficient as the frontier points. Thus, the problem of differential prices, though present, is not likely to have altered the results.

The use of frontier points alone, is, of course, a substantial departure from most production function analysis.[1] Moreover, in our sample the frontier often consists of only two points. It is therefore conceivable that stochastic elements may exert an undue influence on the results. However, the nature of the data permits one to allow for some of the major stochastic elements. In particular, output is measured as potential output given the current plant. Thus, adjustments are made for variations due either to a shortage of raw materials or inadequate demand. Moreover, the plant profiles

[1]With the exception of the work of Farrell (7), Aigner and Chu (1), and Diaz-Alejandro (6), most estimated production functions have been "average" ones, reflecting average practice, not the best available one.

indicate when a plant began operating so that inefficiency due to startup can be identified. The major remaining stochastic element is the possibility of "x" inefficiency, i.e., a point which is dominated may not represent an inefficient technology but inept management, insufficiently motivated workers, unskilled workers or foremen, etc. Such a situation could clearly lead to a modification of our results. Thus, a dominated labor intensive process could conceivably be more efficient than any alternative process if the level of supervision were improved. Or a situation which appears to permit a choice between alternative techniques may not in fact offer a meaningful choice as some dominated, capital intensive point, would, with a change in management efficiency, dominate all other points. It is impossible at this point to establish whether such possibilities are important empirical phenomena. At this stage in the analysis of microeconomic production possibilities, it seems to us that insights provided by our procedure warrant the investigation. As more observations become available they can be incorporated into the present analysis.

II. Empirical Results

Table 1 lists the industries which we have examined, the elasticity of substitution among the frontier points, and whether certain features characterize the firms on the frontier. The factors considered are economies of scale, age of equipment and differential skill mixes.

In all six industries the elasticity of substitution exceeds unity and with the exception of cotton spinning is much higher than unity. In general, these are much higher substitution elasticities than those found in earlier studies using cross section or time series data. We shall return to the possible sources of difference with some of these studies later, but it

is well to remember that our method is not directly comparable as we are using only frontier points, not fitting curves to all observations.

It is important to keep in mind what such high substitution elasticities imply. They do not necessarily mean that there is considerable substitution in primary processes, whether it be the grinding of wheat or the shaping of bicycle parts. Rather, for the production process as a whole, including auxiliary activities, substantial labor-capital substitution is possible. Substitution may take the form of using unskilled labor for material movement rather than conveyors or fork lift trucks, or using simple, labor intensive filling devices rather than automated, large volume filling machines. Indeed, in the one industry where appropriate data were obtainable (grain milling), the difference between auxiliary and direct activities was the major source of difference between capital and labor intensive firms.

The elasticity of substitution was calculated as

$$\frac{\left(\frac{K}{L}\right)_i}{\left(\frac{K}{L}\right)_j} = \left[\frac{\left(\frac{W}{R}\right)_i}{\left(\frac{W}{R}\right)_j}\right]^{\sigma}$$

W is the wage paid to production workers, R the price of capital was assumed to be the same for all companies on the frontier isoquant. However, it is often said that within a given country labor intensive firms (at least if they are smaller) pay <u>more</u> for capital. But this is not necessarily true across countries: problems of differences in interest rates, depreciation and tax laws arise. For the industries where both frontier firms are from the same country, namely, bicycles, tires and woolen yarns, the assumption that the labor intensive firm pays 50 percent more for capital leads to the following changes in σ :

bicycles	3.5	1.9
tires	1.7	1.4
wool	1.4	1.1

These elasticities remain high relative to the usual results.

We turn now to an examination of the characteristics associated with the high elasticities of substitution.

Economies of Scale

Economies of scale do not appear to play a role in determining efficiency. Only a few observations which lie on the frontiers were generated by firms with the largest output. This does not mean that in the industries considered none of the operations is subject to increasing returns. Indeed, it is quite likely that increasing returns are of some importance in a number of the processes. Thus, in paint production, paint mixing is done in large tanks, and, as is well known, the capacity (volume) increases more rapidly than cost (which is proportional to tank area). Nevertheless, mixing is only one operation among many such as material movement, filling, and storage. Such operations constitute a considerable part of the production process and the absence of economies of scale in these operations may mask those which occur in the primary production activity. In any event, economies of scale appear to play no role in determining the possibility of substitution, at least at the output levels included in our observations.

Skill Mix

It is sometimes suggested, and it is intuitively plausible, that newer equipment (involving higher capital-labor ratios) substitutes for skilled production workers. The popular image of a modern factory often involves two workers flipping dials, whereas older plants have large numbers of skilled workers. It is difficult to support this hypothesis with the data at

Table 1

Elasticity of Substitution and Other Production Characteristics

Industry	Elasticity of Substitution	Presence of Scale Economies	Skill Differentials Among Efficient Firms	Age Differences in Equipment Among Efficient Firms
Bicycles	3.5	no	no	no
Wheat Milling	2.7	no	yes	no
Paints	1.4	no	no	yes
Tires	1.7	no	yes	yes
Cotton Spinning	1.1	no	no	yes
Woolen Yarns	1.4	no	no	no

hand. In only two industries, grain milling and tire production was there evidence that capital intensive firms had a significantly lower percentage of skilled workers.

However, to expect systematic differences in skill distribution is probably too facile. Even if newer machines replace skilled operators, there may need to be substantial increases in the staff of skilled maintenance workers necessary to keep them in working order. Second, just as one does not usually proportionally increase the number of supervisors when one takes on more workers, so also when the number of workers is reduced because machines are used in their place, the number of supervisors may not be decreased in proportion to the change in total labor force. For example, if foremen supervise one operation each and the number of operations remain the same, but the number of workers employed on each declines, the ratio of foremen to labor force will actually increase. Given this effect and increased maintenance requirements, it would be surprising if the percentage of skilled workers was systematically lower in the capital intensive firms unless the displacement of skilled operatives is quite substantial.

Age of Equipment

In three industries (paints, tires, cotton) the efficient labor intensive firm had considerably older equipment than the more capital intensive firm. It is important to keep in mind that efficient production with old equipment is not a statistical artifact resulting from using depreciated historical values as a measure of capital stock: capital stock is valued in our data at current replacement cost.[1] Older style machines which may be appropriate, given LDC factor prices continue to be produced, apparently for use by smaller firms in developed countries. Thus, semi-automatic looms continue

[1]It is worth noting here that UNIDO did not produce replacement estimates where current replacement would mean substantial upgrading in machine quality [16, p. 97].

to be available from a number of countries. These older machines appear to be an important potential source of labor deepening in three of the industries we have considered.

Intermediate Factors

Finally, we consider possible differences in the efficiency of the use of intermediate products. It would not be surprising if one incentive to adopt more automated equipment was the possibility of more efficient use of intermediate inputs. To measure such efficiency would require data collected for input-output purposes, i.e., column vectors of each type of purchase for each firm. This, of course, is not available. Moreover, the degree of value added differs across firms. Some bicycle producers purchase seats, others leather from which seats are made internally. Thus, value added to gross output ratios (quite apart from questions of market imperfections) are of little use. In the few cases where a single major input can be identified, e.g., in grain milling and cotton and wool processing, the ratios of final output to purchased intermediates are quite similar for both capital and labor intensive firms.

Shifts

The elasticities of substitution presented in Table 1 do not reflect differences in the number of shifts worked. In two industries, paint and grain milling, the companies on the frontier did not work the same number of shifts. Explicitly allowing for differences in shifts changes the results in these two industries. In paint, if it is assumed that the one shift Japanese plant would exhibit one-third the realized capital-output ratio if it worked three shifts (as does the Indian plant), then it would dominate the Indian

plant, as it would have about the same capital-output ratio, but a substantially lower labor-output ratio. Thus, the effective isoquant would be reduced to one point. On the other hand, in grain milling the effect of the labor intensive Japanese plant working three shifts (as does the Israeli firm) would be an increase in the elasticity of substitution to 4.2. These illustrations yield an obvious lesson. Even in industries where there appears to be limited technical substitutability, LDC's can still increase the labor intensity of their production methods by choosing multiple shift production. In this respect Indian industry as characterized by the firms in our sample seems to be quite successful compared with other LDC's (17).

Some Comparisons

The high magnitudes of the elasticities of substitution presented here suggest much greater substitutability than have other studies. The existing study with which ours is most comparable is that of Clague (4) on which σ is estimated using both engineering and accounting data from the U.S. and Peru. Admittedly, most of the industries are different (except for cotton spinning and tires): however, there is some additional overlap, e.g., paints are a subsector of the chemical branch. Clague does not use observations from individual firms, but industry wide averages. This has the usual advantages of averages but does not permit an independent estimate of the production frontier. Further, in my sample the use of averages would mask substantial (four or five-fold) intracountry differences in both capital-labor ratios and wage rates. Though this is likely to be the major source of difference between the two sets of results, two other points are relevant. First, it is likely that much of Peru's equipment is purchased from the U.S. while the sources of equipment in our sample range

from domestic Indian equipment to German and Belgian equipment. Thus, a major source of potential difference in production methods is eliminated as the U.S. is likely to produce a much more limited range of goods than do India and Germany combined. Second, Clague measures capital in a different way. To obtain a measure of yearly input, rather than a stock, an assumption about differential service life is necessary. Clague assumes a longer life in Peru than in the U.S., thus lowering the capital-labor ratio in the former relative to the latter. On the other hand I have implicitly assumed a uniform service life as it is not obvious whether lower maintenance costs, in say India, offset the probability of less competent maintenance, especially on more complicated machinery.

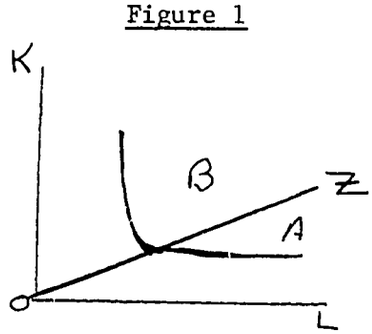
The ACMS paper (2) estimated σ using comparisons between Japan and the U.S. and derived lower elasticities than those reported here. Again, some of the difference may be attributable to their use of average figures. In addition, the UNIDO data indicate that the Japanese tend towards one shift operation. This would lead to an understatement of capital-labor ratio differences. For example, a U.S. plant operated 24 hours with triple the (one shift) capital-labor ratio of a Japanese plant would appear no more capital intensive than the Japanese one shift plant. If differential capacity utilization is not allowed for, it is likely that significant underestimates of the elasticity of substitution will occur. In addition, the ACMS study apparently used <u>all</u> workers rather than only production workers in their calculation of capital-labor ratios. However, if advanced countries employ more office, sales and executive workers per direct production worker, then the difference in capital per production worker will be understated unless this separation is made. Insofar, as the efficient capital intensive firms in our

sample were usually Japanese or Israeli and these exhibit higher ratios of nonproduction to production workers than the labor intensive Indian plants, the use of all workers in our denominator would have resulted in lower elasticities.

Further Considerations

Throughout the preceding we have concentrated on efficiency points. Some interesting types of information are provided by the dominated points. In a country such as India with extensive urban unemployment, it might be assumed that substantial social pressure exists which forces firms to hire redundant workers. This might well result in Indian firms being off the frontier but concentrated around low capital-labor ratios. Thus if OZ (in Figure 1) is a ray from the origin through the most labor intensive point

Figure 1



on the efficiency frontier, it might be expected that firms off the frontier would operate in region A, to the right of OZ.[1] Surprisingly, there is little systematic evidence for this. Inefficient Indian firms were much more likely to be in region B than in A, i.e., inefficient management seems to be associated

[1]A point in A would of course not be voluntarily chosen by a profit maximizing firm: if OZ is the ridge line, then points in A are associated with zero marginal productivity of labor and a positive wage reduces profits. On the other hand social pressures, both from the community and the government may lead to such actions. Thus, the tripartite agreement in Kenya between labor, business and government has called for an increase of 10 percent in the labor force of individual firms. Such imposed agreements, rather than social pressure, are unlikely to lead to permanent "overemployment" as workers hired under the agreement simply substitute for workers who would have been hired as firms expand.

with capital intensive methods.[1] This does not disprove the well-known Hirschman hypothesis of the benefits of machine paced operations, as it is, of course, possible for capital intensive firms still to be a long way from the continuity of material flow envisioned by Hirschman.

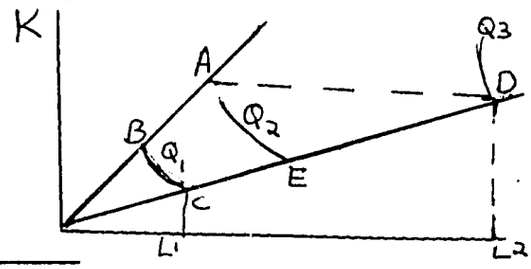
Another point of interest is the magnitude of the benefits which would accrue to a national economy if all firms in an industry were as efficient as the most efficient labor intensive firm within the country.[2] We calculated this for India as it was the most heavily represented country in our sample. The potential benefits from such reallocation include both potential gains in output and employment. The magnitude of the former is simply

$$(1) \quad \Delta Y = \sum_i K_i \left(\frac{1}{k_j} - \frac{1}{k_i}\right)$$

where K_i is the (equipment) capital stock of firm i, k_j is the capital output ratio of the efficient labor intensive firm, j, and k_i the current capital-output ratio of firm i. This expression can be written as

$$(1') \quad \Delta Y = K_i \left[\left(\frac{1}{k_j} - \frac{1}{k_i'}\right) + \left(\frac{1}{k_i'} - \frac{1}{k_i}\right)\right]$$

where k_i is the capital-output ratio of a firm which has the same capital-labor ratio as firm i, but is efficient. Geometrically the benefits of firm i, initially at A, (Figure II) adopting the production technique of firm j (at C)



[1]Ideally, if firm level observations were available for two or more years the relation between management bias and the types of inputs used could be estimated. See (14). The original ACMS comparisons of the American and Japanese relative efficiency assumed neutral efficiency differences, i.e., the degree of inefficiency does not depend on the capital-labor ratio chosen.

[2]This does not necessarily imply that the "reference" firm is on the international frontier calculated earlier. However, if three of the four industries for which the calculation was made, the reference firm was on the efficient isoquant.

can be envisioned as consisting of (1) a pure efficiency gain in output of $K_i \left[\frac{1}{k_i'} - \frac{1}{k_i}\right]$ = AB = CE and (2) an increase in output due to the shift to the labor intensive method of $K_i \left[\frac{1}{k_j} - \frac{1}{k_i'}\right]$ = ED.[1] As initial output is indicated by the distance OC, the gain in total output is CD. The increase in employment is L_1 L_2. Such a change would, of course, require an alteration in relative factor prices to make production at D optimal for the individual firm.

The calculated changes in value added and employment are shown in Table 11. They are quite large: however, given recent estimates of the magnitude of domestic inefficiency generated by distorted foreign trade structures (including tariffs and quotas), the income estimates are not all that surprising. What is surprising is the large amount of foregone employment. This is presumably attributable to the existence of substantial protection which allows artificially high wages (and profits) to be realized and causes firms to choose relatively capital intensive methods. Policies which reduce existing distortions may increase employment as well as national income.

These results are of considerable interest as they strengthen the conclusion that there is no tradeoff between employment and output. But it is important to remember the difference between the lack of tradeoff revealed in these data and that implied by the above results of significant elasticities of substitution. The earlier results simply demonstrate the possibility of efficient substitution along a frontier. Table II shows that if existing firms are operating at less then maximum feasible labor-capital ratios, output and employment growth could be obtained via a shift to such techniques. For efficient, capital intensive firms, the gain to be realized is solely that from the change in technique. For all others there is, in addition, the gain from greater efficiency.

[1]The isoquants labelled Q_1 Q_2 Q_3 are assumed to exhibit constant returns to scale. Output at A and C are equal by assumption. The isoquant Q_2, ($Q_2 > Q_1$) goes through A; thus if the initially inefficiently used resources at A were utilized as efficiently as those at B, output would equal Q_2.

Table II

Benefits from Reallocation Within Industries

	Increases in	
	Employment	Output (value added)
Bicycles	72%	41%
Cotton Spinning	15	84
Wool Processing	445	64
Paint Production	318	270

The estimated gains are maximum ones as they assume that existing equipment is sufficiently flexible to permit substantially more labor to cooperate with it and that there will be a change in the economic milieu leading to greater productive efficiency. If the more plausible assumptions are made of limited post-installation flexibility and only gradual changes in the economic environment, then the numbers in Table II represent foregone employment (and output) rather than actual benefits achieveable from reallocation.

Conclusions

The preceding results suggest that considerable substitution possibilities exist in a number of manufacturing industries. Assume that similar results held for other industries. What are the policy implications?

First, it is unlikely that a change in relative factor prices can have much current impact on production methods. Capital already in place is likely to have limited substitution possibilities; different relative prices can only affect expansion decisions. However, one potential important effect may be the encouragement of multiple shift production which, as we have seen, can result in a substantial increase in labor intensity even where the basic production process seems to offer limited substitution.

Over the longer run changes in relative prices could lead to more labor absorption in view of the high estimates of the elasticity of substitution found in this study. One constraint on such changes should be considered, namely, it is quite possible that capital intensive processes substitute capital for skilled labor, though we have found only limited evidence to support this contention. If this were a generally important phenomenon, increasing labor intensity could be envisioned as a process in which skilled

labor grew relative to unskilled labor with possibly adverse distributional impact. The immediate effect of such a displacement would depend on the partial elasticities of substitution among the factors of production and the degree of factor market competitiveness. The total employment impact would also have to take into account the propensities to consume particular products by each group and the possibility that the labor intensity of the respective market baskets may differ. Thus a balanced policy evaluation of the desirability of using more labor intensive processes would require considerably more information than the simple fact that such substitution is feasible.

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