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TECHNOLOGICAL TRANSFER, LABOR ABSORPTION, AND ECONOMIC DEVELOPMENT

Howard Pack
and
Michael Todaro

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I. Introduction

The choice of an appropriate technology for underdeveloped countries has been a major source of controversy amoung development economists for well over two decades. One fundamental issue around which the controversy centers is whether or not the available techology currently being produced in the advanced Western countries is appropriate for adoption in less developed countries (LDC). Specifically, it is often argued that given the relative abundance of manpower, poor countries may be undermining their own self interest by indiscriminate adoption of the labor saving equipment which has emerged as the natural response of developed countries to their own labor scarcities. The economic rationale usually provided for this argument is the textbook dictum that static efficiency requires the equilibration of marginal rates of factor substitution and the (implicit) wage-rental ratio. Given then the relatively low wage-rental ratios prevailing in LDC's, this criterion would seem to imply the wisdom of adopting labor-intensive techniques.[1] The fundamental fact remains, however, that much of the equipment used in the LDC's must be imported from the developed nations with the result that the range of actual technological choice is to a large extent limited by the technical specifications of imported Western equipment. Thus the possibilities of choosing labor intensive techniques is reduced by the fact that most new equipment is actually

[1]For a summary of the various arguments and an extensive bibliography see H. B. Chenery, "Comparative Advantage and Development Policy," American Economic Review (March 1961).

relatively capital intensive and therefore undesirable (from the social viewpoint) while the older, more labor intensive equipment is either no longer being produced or is limited in supply and expensive to maintain.[1]

Viewing this importation process in its most fundamental form, we believe that it crystallizes as a choice between new, modern equipment, regardless of country of origin and old, used equipment--the former being considerably more capital intensive than the latter. Thus, although the new equipment may provide some range of alternative factor intensities, e.g., Japanese equipment may be somewhat more labor using than American equipment of the same vintage--both are likely to be labor saving vis-a-vis the existing twenty-year old equipment from these same countries. The importation process determines the range of technical choice (i.e., the set of feasible factor combinations bounded on one side by the most modern labor saving equipment and on the other by the oldest profitable labor using equipment), dictated largely by the history of technological progress in developed countries as well as the speed and direction which this process will take in the future and inevitably reflects the economic imperatives of the developed countries. This will be true regardless of whether the less developed country adheres to a policy of importing new or used equipment. The process is depicted in Figure 1, where say t

[1]Some evidence suggests that both Japanese and Russian development was accompanied by some substitution of labor for capital in auxiliary activities such as movement of materials. However, while there are undoubtedly some short run possibilities for additional labor absorption, the dynamic labor saving bias inherent in Western technological progress greatly limits the possibilities of significant long run labor absorption. For discussions of the Japanese and Russian experience see G. Ranis, "Factor Proportions in Japanese Economic Development," American Economic Review, XLVII (September 1957), pp. 594-606, and D. Granick, "Economic Development and Productivity Analysis: The Case of Soviet Metal Working Industry," The Quarterly Journal of Economics, LXXI (May 1957), pp. 205-233.

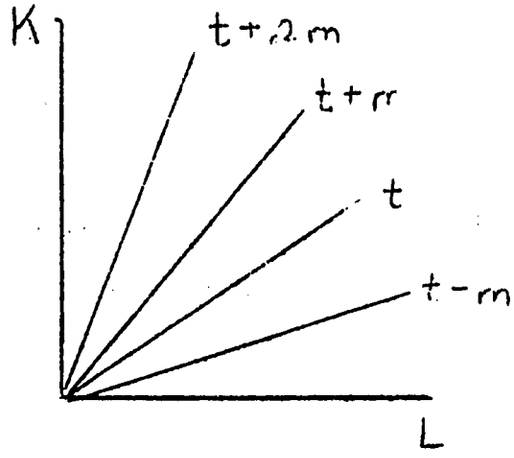

Figure 1

represents the factor proportions associated with the currently produced technology and (t - m) reflects the factor proportions on the used equipment which is being scrapped by the developed country and m represents the average age of the developed nation's capital stock. Over time this year's technology becomes the scrapped technology of m years hence, so that the triangular 'pencil' formed by points t, 0, and (t - m) shown in Figure 1 rotates to the left, e.g., to (t + 2m), 0, (t + m), with an appropriate renumbering of the isoquants to reflect the continued progress of technology. The implication is clear. Since the LDC's must import their technology from the West, they are forced to follow the bias inherent in this process regardless of whether or not such a process is in their long run interests.

Viewed in terms of the dynamics of technological transfer depicted above, the forceful but static argument that LDC's might profitably adopt used equipment to accelerate the process of labor absorption emerges as somewhat myopic. With output growing and replacement as well as net

investment being required, even the extreme assumption that all gross investment is satisfied by the continuous importation of used equipment, will still imply an increasing divergence between output and employment growth rates since the limited supply of vintage (t - m) equipment forces a switch to used equipment of a later vintage with its lower labor coefficient. This switching is required even when existing factor prices would lead firms to choose the purchase of more equipment of vintage (t - m). Consequently, given the present abundance of labor and the prospective rapid increase in the potential industrial labor force, it follows that regardless of whether the used equipment is actually economically more efficient in terms of static unit costs than the modern capital intensive equipment, the prospects for significant long run labor absorption in the industrial sector become rather dubious.[1]

The question then arises as to what are the alternatives. In our representation of the process of technological transfer, as long as the LDC's have no control over the direction and speed of technical change, the goals of industrial growth with significant labor absorption will be exceedingly difficult to realize.

Given the structure of world trading patterns, as long as capital goods production is concentrated almost exlusively in developed countries, the relatively insignificant demands of the LDC's for these goods will have only a negligible impact on both current production decisions about

[1]For some cross-sectional data on this employment lag see United Nations, Department of Economic and Social Affairs, The Growth of World Industry, 1938 1961: National Tables (New York, 1963). See also the follow-up study, Growth of World Industry, 1938-1961, International Analyses and Tables (New York, 1965), especially p. 92.

the type of machine to be produced and more importantly on the direction that factor saving bias will take in the future. It is for these reasons that we would argue for the creation of domestic capital goods industries in less developed countries in which production is geared to their own long run technological requirements.

II. Generating a Domestic Machine Producing Capacity

The question of establishing domestic capital goods capacity has rarely been given serious consideration in the development literature. Even when it has been discussed, the emphasis has been largely in terms of saving foreign exchange and cost comparisons of domestic production with that of equipment currently produced in the West.[1] Abstracting from foreign exchange considerations (which we believe to be certainly important) the adoption and encouragement of a domestic machine producing industry capable of producing efficient labor using techniques for other industries is justified in its own right when considered in the context of our earlier discussion of the speed and direction of technical change in the West. Let us state explicitly that the establishment of this industry is not put forth as a solution to the employment problem at the cost of decreasing the rate of growth of output through the adoption of inefficient techniques. Rather, it is proposed on the assumption that both output and employment growth can be accelerated. Specifically, we would argue that the LDC's should produce their own machinery, copying initially the earlier more labor-intensive designs of the Western countries. This would provide the possibility of eliminating much of the conflict between output and employ-

[1] For example, see United Nations, The Manufacture of Industrial Machinery and Equipment in Latin America I. Basic Equipment in Brazil (New York, 1963).

ment growth while avoiding the important difficulty of designing new, labor-using machinery. By duplicating earlier Western equipment they would derive the benefit of controlling both the direction and speed of technical change in their own countries. In effect, this would reverse the direction of technical progress from the viewpoint of the LDC's since the current trends in the Western countries would no longer be a determining feature of the factor-using bias in the LDC's. The copying of older, Western technology would be capital saving *vis-a-vis* the equipment which may be currently imported from the West. Moreover, if urban unemployment is eventually eliminated, the existence of a domesti capital goods industry allows the adoption of more recent labor-saving techniques to be introduced at a speed consistent with changing domesti factor availabilities. In effect, then, the domestic production of cap tal goods in the LDC's would allow output expansion to continue along process (t - m) in Figure 1 as opposed to the forced adoption of more capital intensive techniques due to the unavailability of vintage (t - m) equipment. Not only would this process alleviate the employment lag but it also could well be a major source of external economies to the non-capital goods sector, especially in providing skilled workers to these other sectors.[1] In addition, the possibilities of altering the receive Western blueprints in a labor-intensive way is greater with the existence of a domestic capital goods industry as domestic users of equipment are enabled to work closely with the producers, a feature which is of cons erable importance given the "made to order" nature of most machinery.

[1]Nathan Rosenberg has argued that in the United States there wer major external benefits derived from the expansion of the capital goods industry. See his "Technological Change in the Machine Tool Industry, 1840-1910," Journal of Economic History, XXIII (December 1963), pp. 414-43.

Finally, another possible benefit derived from duplicating equipment which has previously been produced is the absence of the need for a large corps of engineers who can design new machinery, although undoubtedly some engineers would still be required.

Although it is often thought to be a capital-intensive branch, machinery production is in fact one of the more labor-intensive industrial branches in most economies. For example, in the U.S. the capital-labor ratio in the machine producing branches is relatively low.[1] Perhaps more interesting from the point of view of the LDC's is the very low capital-labor ratio found for Japanese machinery industry in 1951 as shown in Table 1; of twenty-one branches, only seven had lower capital-labor ratios. One explanation of this phenomenon lies in the nature of the machine

Table 1

Direct Capital-Labor Ratios in Japanese Manufacturing - 1951

Petroleum products	1.200	Metal mining	.172
Coal products	.682	Fishing	.170
Nonferrous metal	.363	Machinery and electrical equipment	.161
Chemicals	.338	Apparel	.132
Iron and steel	.337	Textiles	.131
Nonmetallic mineral products	.298	Paper	.120
Nonmetallic minerals	.199	Rubber	.119
Processed foods	.193	Lumber and wood	.111
Grain mill products	.193	Printing	.093
Shipbuilding	.174	Leather	.068
Transport equipment	.174		

SOURCE: Institute for Social and Economic Research, Osaka University (mimeo).

producing technology. It is most often not amenable to mass production methods as production takes place in response to specific orders embodying

[1]See W. W. Leontief, Input-Output Economics (London: Oxford University Press, 1966), pp. 129-133.

differing specifications, while mass production requires a continuous flow of similar products. The foundation of the misconception of the branch's capital intensity lies in the confusion between the direct and total input structure. While some branches which produce important inputs to the machine branch, particularly metals, are themselves very capital intensive, there is no necessity to produce these domestically, even if domestic machines are produced. Not only is the machinery branch not a heavy user of capital, but it offers the advantage that small scale production may be relatively efficient. The absence of substantial economies of scale is the result of the specialized, non-mass production nature of the industry, although for some types of machinery, particularly agricultural equipment, large scale production may be possible. On the other hand, as Nathan Rosenberg has suggested, there may be "economies of specialization," i.e., firms producing only a limited range of machinery such as looms may acquire greater facility in producing even small numbers of machines. Such specialization may, of course, be limited by the size of the domestic market. Here, however, the possibilities for division of labor among many of the LDC's are obvious. Moreover, as we shall suggest below, the existence of capital goods industries in these countries could provide an important means of transmission of technical knowledge relevant to their own specific resource endowments.

The main precondition for the establishment of a capital goods industry is the creation of an appropriate pool of skilled and semi-skilled labor if it does not already exist. Unfortunately, rela-

tively little systematic effort has been devoted to analyzing the training requirements for given industries. However, work on the United States economy by Richard Eckaus provides some guidelines to the type and intensity of training likely to be required.[1] Using education and vocational training requirements for occupations prepared by the U. S. Bureau of Labor Statistics, Eckaus calculated the average amount of training required by workers in each branch of U. S. industry. While the average years of schooling required is 11, similar to that in most branches, the average period of vocational training in the machine producing industries is 1.77, one of the longest. These figures conform with the general impression that this branch is particularly skill intensive. However, from the viewpoint of establishing capital goods production capacity, Eckaus' data probably overstates the preparation period as they include the training of large numbers of engineers who are involved in the designing and testing of equipment.[2] Engineers and other technicians would presumably be needed only in much smaller proportions if designs were in fact copied from the developed countries. Moreover, the U. S. data reflect skills needed in producing products such as turbines and sophisticated machine tools, whereas we would hardly suggest that such complicated products be produced during the early stages of a capital goods industry.

[1]Richard Eckaus, "Economic Criteria for Education and Training," Review of Economics and Statistics (May 1964).

[2]However, variations in natural conditions, e.g., mineral availabilities may still require some additional designing and testing of equipment.

Even ignoring these biases, the education and training requirements are less formidable when one allows for the fact that the absolute numbers of workers to be involved in the branch is likely to be small. While the costs of training may be larger than those for other branches, they may be viewed as an investment whose returns are likely to be quite high.

Although developed countries might well have a comparative advantage in the production of such equipment, there are numerous reasons why they are unlikely to engage in such production. Foremost among these is the fact that capital goods producers typically envision the markets of LDC's as being highly volatile due to political as well as economic instability. Since there is no domestic market for this equipment and since the variance in expected returns is likely to be substantial given the aforementioned uncertainties, the costs of creating the necessary additional capacity may not be warranted, given the assured returns from the domestic market.

Assuming the will and the capacity to establish the branch, is its output likely to be competitive with that of foreign producers? First, it must be emphasized that in an important sense this question is not entirely relevant as there would be no comparable equipment of old design currently being produced in the Western countries for export to the less developed countries. It should be noted, however, that if the labor-using machines actually produced in the LDC also resulted in higher unit capital costs than the labor saving equipment of the advanced countries,

then it would pay to forego the establishment of the capital goods industry unless there was a reasonable presumption that infant industry arguments had validity. But, as shown below, available evidence suggests that even where competitive equipment is being produced, adverse cost conditions are not likely to be the case. This is not too surprising as we have seen that the most important factor of production is skilled labor and its price is likely to be very low in comparison with comparable labor in the advanced countries. For example, a recent ECLA study in Brazil calculated the cruzeiro prices of domestically produced machines and machine components per dollar of imported machines to be as shown in Table 2.

At the time of the study the free market rate was 180 cruzeiros per dollar and the rate established under the exchange auction system was 250 cruzeiros per dollar. Thus many of the goods were produced at a price which was less than the international price using even the lower exchange rate and all were as cheap or cheaper when the auction rate, which probably is a better indicator of scarcity value, is used.

Similarly, the machine tool branch in Argentina has been exceptionally successful, output expanding rapidly at prices low enough to allow almost $2 million of exports annually during the years from 1963 to 1965.[1] And, an analysis of the structure of the Israeli economy for 1958 indicated that the real costs of saving

[1]ECLA, La Fabricación de Maquinerias y Equipos Industriales en America Latina: IV Las Maquinas-Herranuentas en la Argentina (Santiago de Chile, 1966), pp. 73-77, cited in Carlos Diaz-Alejandro, Essays on the Economic History of the Argentine Republic, forthcoming.

Domestic Production Cost in Cruzeiros
Divided by Dollar Cost of Imported Equipment

Type of Equipment	Cruzeiros per Dollar
Metal structure: direct fired furnaces	160.00
Pressure vessels (towers and pressure storage)	163.00
Large-diameter welded tubes	170.00
Storage tanks: steam generator-mixers	172.00
Electrical equipment - electricity ducts, tubing - steel and forged iron tubes, refractories and thermal insulation material	180.00
Heat exchanges and surface condensers	183.00
Cyclones	185.00
Traveling cranes: lifts and lifting tackle	190.00
Tubing - connections - expansion joints	200.00
Pumps and compressors	220.00
Electrical equipment - motors and transformers	250.00

SOURCE: United Nations, The Manufacture of Industrial Machinery and Equipment in Latin America I. Basic Equipment in Brazil (New York, 1963), p. 20.

a dollar of imports in the machinery branch were among the lowest to be found in any branch in industry, despite the small size of the sector.[1]

Finally, support is provided in a study by R. Soligo and J. Stern[2] of the effective tariff rate (the rate of protection of value added) in Pakistan. Their data show that the effective rate of protection of machinery is the lowest for any group of products in Pakistan. Nevertheless, the rate of growth of output in this branch has been very rapid. Thus,

[1] M. Bruno, Interdependence, Resource Use and Structural Change in Israel (Jerusalem: Bank of Israel, 1962).

[2] "Tariff Protection, Import Substitution and Investment Efficiency in Pakistan," Pakistan Development Review (Summer, 1965).

despite the lack of tariff protection, profitability in machine production must be quite high, implying that the branch may have a comparative advantage.

Thus, available evidence, although by no means complete, does conform to our initial expectation that the LDC's may well be competitive even in the production of the most modern capital goods.[1] Moreover, apart from the advantages to be derived from the production of efficient, labor intensive machines, other benefits would certainly be significant. Foreign exchange shortages frequently interrupt development programs resulting in either an interruption in the investment program or a reduction in the current rate of production as intermediate imports are cut back. Assuming that the shortage results from a foreign exchange gap rather than a savings constraint, the existence of domestic capital producing capacity eliminates to an important extent the need to obtain foreign exchange in order to transform savings into real investment goods.[2] Finally, even if few individual LDC's could expect to produce the full range of capital goods, trade among them could still eliminate the foreign exchange bottleneck, which given current geographic distribution of capital goods production, often is tantamount to a lack of exports to the advanced countries.

The dynamic benefits obtainable from equipment production are also important to consider. One result of the recent outpouring of literature on production functions and technological change has been to focus atten-

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[1]It is also likely that in most of these countries the competitiveness of the existing branches is probably understated as their raw material costs, particularly of metals, are above world levels as a result of their use of high cost domestically produced metals.

[2]For an early statement of the problem which anticipated much of the recent "two gap" literature see E. D. Domar, "A Soviet Model of Growth" Essays in the Theory of Economic Growth (New York: Oxford University Press, 1957).

tion on the likelihood that technical change is often embodied in new equipment.[1] Assuming this approach to contain a substantial amount of descriptive power, the question arises as to the source of these improvements. There is historical evidence that a large part of this change has its origin in the capital goods branches themselves, those actually employed in the branch constituting an important source of new ideas.[2] However, there is still considerable scope for further investigation of this important question.

Finally, the existence of a capital goods sector may constitute a necessary condition for changes in design which respond to domestic relative factor scarcities in the economy. Although there are at present clear directions in which a capital-saving technology could develop,[3] the machine producing industry in the west is, for a variety of reasons, unlikely to follow this course. Thus, in the final analysis, the long run economic aspirations of less developed nations might depend largely on the successful adoption and continued growth of a domestic capital goods industry.

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[1]See R. M. Solow, "Investment and Technical Progress" Mathematical Methods in the Social Sciences (Stanford, 1960). For a recent discussion of the difficulty of actually measuring such change, see D. Jorgenson, "The Embodiment Hypothesis," Journal of Political Economy (February 1966).

[2]N. Rosenberg in "Capital Goods, Technology and Economic Growth," Oxford Economic Papers (November 1963), provides many examples from U. S. economic history.

[3]For a suggestive analysis of these possibilities see G. K. Boon, Economic Choice of Human and Physical Factors in Production (Amsterdam: North Holland Publishing Co., 1964), pp. 59-65