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9. ABSTRACT

A serious problem in LDCs is that unemployment is high and wages are low, yet most new manufacturing enterprises established are capital-intensive. They provide relatively few new jobs. This raises a set of critical questions: Are the high capital-labor ratios in LDC manufacturing necessary? Are there more efficient alternatives? If so, why have they not been used? If not, what are prospects for creating them? This paper presents a non-technical review of the evidence concerning the processes and institutions relating to creating new technology in LDCs. The evidence indicates substantial possibilities for labor-capital substitution, particularly when possibilities for international trade are acknowledged. One of the reasons capital-intensive enterprises are launched in LDCs is that factor prices favor them. Another is the absence of competitive markets; this allows the instincts of the engineer to prevail. The engineer designs, a process that is optimal in terms of labor efficiency in a developed country. But such processes are not optimal in an LDC that lacks capital but has low wages and much unemployment. The evidence suggests that incentives are very important. Appropriate factor prices are an important incentive, as is effective competition in product markets. This would leave less scope for engineering instincts to dominate efficient factor use. The subsidies of capital use must be ended. An important part of this would be the replacement of exchange control and over-valued exchange rates with a realistic exchange rate. If wages in the modern urban sector cannot be decreased, at least their rates of increase must be moderated. They are too high in comparison with the incomes of the rest of the labor force in the LDCs. Wage increases in the urban sector must necessarily reduce the potential for improving the incomes of the poorer majority.

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Appropriate Factor Proportions for Manufacturing in Less Developed Countries: A Survey of the Evidence

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I. Introduction

The question of appropriate factor proportions in LDCs has emerged as one of the most important development problems of the 1970s. High and rising rates of unemployment in urban areas pose major political and economic problems for LDCs. Simultaneously, employment in manufacturing is frequently growing far more slowly than the growth of manufacturing output. The high capital intensity of LDC manufacturing is frequently cited as the cause of these phenomena. Capital-labor ratios for new or proposed industrial projects in LDCs are frequently $15,000 or more per worker, and facilities in the petrochemical industry can run as high as $200,000 per worker (Morawetz, 1974). We shall argue below that the connection between urban unemployment, slow growth of manufacturing employment, and high capital-labor ratios is not as simple as may appear at first glance. But the high and clearly inappropriate capital-labor ratios frequently found in LDCs are nevertheless a genuine and important economic problem.

A critical set of questions can and must be asked about these high capital-labor ratios in LDC manufacturing: Are they necessary? Or are there efficient alternatives for LDCs which are more labor intensive and hence more appropriate for LDCs? What evidence is available on this point? If alternatives are available, why have they not been utilized? If alternatives are not currently available, what are the prospects for

creating them? What are the best ways of creating them? What do we know about the processes and institutions concerned with creating new technology, especially in LDCs?

This paper will provide a non-technical review of the available evidence that can shed light on these questions. Other surveys or summaries that deal explicitly with or touch upon the problem of appropriate technology for LDCs have appeared in recent years by Turnham (1971), Ridker (1971), Jackson (1972), Morawetz (1974), Acharya (1974), Edwards (1974a), Bruton (1973), Westphal (1974), Brown and Usei (1974), OECD (1975), Cline (1975), and Bhalla (1975a, 1975b). But the emphasis of each is somewhat different, and none has focused primarily on the evidence concerning factor proportions and appropriate technologies in manufacturing. That will be the major task of this paper.

The remainder of this paper will be organized as follows: Section II will provide some background by sketching briefly the patterns that many economists would expect to characterize a well-functioning, healthy, growing LDC economy. Against this background, the phenomena of high urban unemployment, lagging manufacturing employment, and high capital-labor ratios can be put into proper perspective.

Section III will briefly summarize the a priori arguments concerning the absence of choice in efficient factor proportions and then will offer a survey of the available evidence. The evidence will be organized around three headings: econometric evidence on the elasticity of substitution of capital for labor; engineering or process analyses of the elasticity of substitution and the availability of choice; and anecdotal evidence. In addition, separate attention will be given to comparison of

large and small firms within LDCs, since many observers feel that these comparisons shed valuable light on the question of choice to the opportunities for the use of used machinery, as a means of efficiently lowering capital-labor ratios for LDCs; and to the evidence concerning multinational corporations and whether they do or do not alter their factor proportions in LDCs. This section will also explore the evidence on relative saving rates in LDCs, since this is sometimes used as a justification for capital intensive methods. And it will examine the possibility of gaining more appropriate factor proportions by encouraging more appropriate product choice in LDCs. In this author's opinion, the evidence indicates substantial possibilities for labor-capital substitution, both among processes and among products, particularly when the possibilities for international trade are acknowledged. More appropriate factor proportions are currently feasible.

Section IV then briefly examines the evidence concerning the reasons why currently feasible appropriate factor proportions are not chosen. Inappropriate factor prices and the absence of competitive markets (which allows the non-optimal instincts of the engineer to prevail) are important causes.

Section V explores the possibilities of developing new products and processes in LDCs, to widen the range of technological choice and to increase the productivity of all resources over time. This usually falls into the category of research and development. Even in developed countries, the systematic evidence concerning R&D is quite limited, and the LDC evidence is considerably more restricted. The available evidence will be discussed and analyzed. Attention will also be given to the role of research institutes, multinational corporations, and patent systems in creating new

knowledge and transferring existing knowledge from the developed countries to the LDCs.

Section VI will offer some conclusions from this survey.

Before proceeding further, we should offer a few definitions that may clarify the discussions in the following sections. By a "technology," we will mean all of the known efficient ways of producing a product or process.[1] Thus, in a favorable case there may be many efficient capital-labor combinations encompassed within a known technology, and better factor utilization for LDCs would only require moving to the lower capital-labor ratios within the known technology; this is the evidence on which Section III largely focuses. In an unfavorable case, there may be only one currently known feasible factor ratio (usually capital intensive), and more appropriate factor combinations for LDCs will have to be newly discovered. This would be considered to be new technology (as would, of course, the discovery of new production processes that were more efficient in using less of all factors to product a unit of output); this is the subject of Section V. The quest for appropriate factor proportions for LDCs, then, includes both efficient changes within known technologies and the discovery of new technologies.

Finally, by "appropriate," we mean factor proportions that are roughly in line with the overall factor availabilities in an economy. The poorer the LDC, the less capital (physical and human) relative to labor we expect to find, and, hence, the more labor intensive the "appropriate" factor proportions would be.[2]

II. The Well-Functioning LDC and the Inappropriate Factor Proportions Problem

Let us imagine an LDC which starts, for whatever reason, with low levels of physical capital and human capital per capita and, consequently, low capabilities of assimilating modern technology. Per capita income will be low. Nevertheless, product and factor markets could still be operating competitively and allocating the (very limited) amount of resources in an efficient fashion.[3] Since unskilled labor is in relative abundance, its wage would be relatively low. With trained skills in relatively short supply, the premium for skilled labor of various kinds would be relatively high. Similarly, relatively scarce capital would earn a high return. Competition and mobility among sectors would ensure that the returns to labor, skills, and physical capital were the same in all sectors of the economy. The relative proportions of labor, skills and physical capital would not be identical in all sectors of the economy, since different sectors have different technologies. Thus, some sectors would be more capital intensive than others, but as long as there were reasonable opportunities for factor substitution, there would be no problem in manufacturing full employment of all factors.

The high returns to skills and to physical capital would induce saving and investment. The increased physical capital would be used to equip new additions to the labor force (reflecting population growth) at prevailing capital-per-worker levels and also to raise those levels generally. The rising levels of capital per capita would gradually raise per capita incomes. Wages for unskilled labor would rise compared to the returns to the now relatively more abundant skills and physical capital. Again, competition and mobility would tend to keep wages and returns equal across all sectors. Rising skill levels would increase the assimilation

of advanced technology, raising incomes yet further. And the additions to human and physical capital would tend to be spread uniformly across sectors, although differences in technologies and in human abilities and proclivities would rule our complete uniformity. Again, competition would ensure this relative uniformity of the additions.

The pattern of expansion of various sectors of the economy (e.g., manufacturing, agriculture, services, etc.) would depend on the pattern of tastes with rising incomes, on technologies, and on the possibilities for international trade. We would expect to see manufacturing grow faster than the overall economy until high income levels were reached.

Let us now focus more closely on the manufacturing sector. Wages in manufacturing (corrected for the cost of living) would tend to be more or less equal with wages in other sectors of the economy. Increases in the amount of capital per worker -- capital deepening -- would take place relatively gradually, at a pace basically consistent with the capital deepening taking place in the rest of the economy. If serious unemployment were somehow to appear, two effects would follow: There would be downward pressure on wages, and the process of capital deepening would temporarily halt until the unemployment had disappeared. It would be less profitable to add more capital to existing workers (because of diminishing returns to capital) than to equip new workers (from the ranks of the unemployed) at existing capital-per-worker levels.

Finally, as manufacturing output rose, we would expect manufacturing employment to rise less rapidly, even in this well functioning economy, for three reasons: the gradual physical capital deepening, gradual human capital deepening, and technological change.[4] All three would

raise the output per worker and hence cause employment growth to lag behind output growth. A rough estimate of this increased productivity factor would be 3%.[5] Thus, if overall manufacturing output were growing at a rate of 8%, we would expect employment to rise by only 5%. Only if there were unemployment (so that capital deepening did not occur), no increases in skill levels, and no technological change (or only labor-augmenting technological change) would we expect employment to rise as rapidly as output.

With this as background, we can now see the connection between urban unemployment, slow employment growth rates, and capital-intensive manufacturing establishments. As we have just argued, the lag of employment growth behind output by itself is not cause for concern. It is the existence of a differential in growth rates in the presence of substantial urban unemployment and (even when open unemployment is low) the existence of differentials in excess of roughly 3% that are causes for concern. New manufacturing projects requiring $15,000 per worker in investment, when the current average capital per worker is less than one-tenth of that, again indicates that the economy is not functioning in the smooth manner of the model.

Finally, the relationship of urban unemployment to these problems needs to be clarified. Many economists have come to believe that the large real wage differentials between the urban modern sector and rural areas. Workers from the countryside are willing to migrate to the cities and sustain periods of unemployment, in order to get the chance to get a high wage job.[6] The high urban wages are non-competitive, in the sense that the unemployment pool would otherwise drive them down, but a combination

can explain much of the urban unemployment.

of legal minimum wages, union pressures, government required fringe benefits, and other government pressures keep the wages high. If this view of the urban unemployment problem is correct,[7] then the high capital-labor ratios in manufacturing, while not helping greatly in solving the problem, are not directly responsible for it. (To the extent that the high wages discourage the use of labor intensive processes, the high capital-labor ratios are another consequence, along with unemployment, of these high wage policies. See Section IV.) Even if lower capital-labor ratios prevailed[8] and employment grew faster, the unemployment would persist as long as the urban-rural real income differential persisted. Only if manufacturing employment grew fast enough, so that enough people were pulled out of the countryside so that incomes in rural areas rose close to urban levels, would the unemployment problem disappear. Thus, the high capital-labor ratios for new manufacturing in the face of high urban unemployment can be seen as an indication that the system is not functioning properly, but the former cannot really be seen as a cause for the latter.

Finally, it may be instructive to see the direct effect of high capital-labor ratios for new manufacturing projects.[9] Let us suppose that an LDC has a per capita income of $500. The country has a current population of 1,000 (for easy computation), growing at 3% per year. Current GNP is $500,000. If the country is investing 18% of GNP,[10] perhaps 12% would be available for net new investment (the remainder covering the replacement of older, worn-out capital). Thus, $60,000 would be currently available for net new investment. With a population of 1,000, the labor force will be around 400. Average capital per worker in the entire economy might be $1,000. If the labor force is also growing at 3%, 12

workers will be added to the labor force.

Now suppose that new manufacturing projects require a relatively high capital-labor ratio -- say, $15,000 per worker.[11] The available investment funds would only stretch as far as equipping four new workers; i.e., only one-third of the new workers would be equipped; the remainder would have no capital with which they could work and presumably would be unemployed or underemployed. Of, if we could equip all of the new workers at the prevailing $1,000 capital per worker level, we would have funds remaining to provide only three and one-half workers with the capital intensive manufacturing jobs. Thus, if unduly capital-intensive manufacturing processes are chosen, not only will capital deepening fail to take place among the existing labor force but at best only a quarter or a third of new entrants into the labor force can be provided with the high productivity capital intensive jobs. With only a small fraction of the overall labor force benefiting from the new investment, a small industrial labor elite may well develop.[12] And, if there are efficient low capital-labor alternatives so that the new investment could be more or less spread over the entire labor force, overall output and income would be higher in this latter case, because of the diminishing marginal productivity of capital when it is all concentrated on a few workers. Thus, though the high productivity from high capital-labor ratios is the eventual goal of economic development, the efficient path to this goal is gradual capital deepening for all rather than sharp capital deepening for a few.

High capital-labor ratios, then, clearly pose serious economic (and social) problems for LDCs. But are there efficient alternatives, or are the high ratios a problem that LDCs must live with until alternative technologies are devised? It is to that evidence that we now turn.

III. Alternative Factor Proportions: The Evidence

The belief that capital intensive manufacturing processes similar to those found in developed countries are the correct ones for LDCs appears to have been very strong in the 1950s and 1960s, especially by engineers and even by some economists. The major argument in favor of them was that they were simply more efficient than any more labor intensive alternatives: the latter, it was claimed, would always use more labor and more capital per unit of output than would the process with the high capital-labor ratio. Thus, though alternatives might exist in a technical sense, they would always be found to be inferior. Statements to this effect can be found in the comments of Nicholas Kaldor (as reported by Robinson [1965, pp. 28-29]), Amin (1969), Barber (1969), Ady (1971), and UNECLA (1970). This could also be characterized as a belief in fixed proportions (as opposed to factor substitutability), since the efficient factor combination is fixed at the proportions found in developed countries.

The identification of efficiency with "productivity" (i.e., labor productivity) by many international study groups and productivity missions in the 1950s and 1960s helped contribute to this view.[12] Though low labor productivity could be due to pure inefficiency (e.g., bad managerial supervision, bad organization of work tasks, etc.), it could also be due to the efficient combination of labor with low levels of capital in poor countries. The confusion of labor productivity with efficiency ✓ meant that high capital-labor ratios would be associated with efficiency.

Another strand of argument has claimed that efficient alternatives might exist for some processes but that the alternatives are limited and hence in practical terms most LDCs are faced with little or no alternatives

to high capital-labor ratios for most manufacturing processes (Stewart, 1972; 1974). Others, like Baranson (1969b, chs 2,3; 1972) and Strassman (1968, pp. 93-102, 155-157) have argued that high levels of mechanization are necessary to ensure high levels of quality (e.g., in machined products) or can substitute for managerial skills in organizing and supervising workers, skills which are even in shorter supply in most LDCs then is capital (Hirschman, 1958, ch. 8).

A completely different line of argument favoring capital intensive technologies has rested on alleged saving and reinvestment rates by different economic groups. As argued by Galenson and Leibenstein (1955), capital intensive technologies would mean high returns to capital, and capital owners have higher saving and re-investment rates than workers. Hence, even though there might be efficient labor intensive methods available, capital intensive methods should be chosen because reinvestment would be greater and the pace of industrialization would proceed faster. This argument clearly hinges on empirical evidence concerning savings rates by different groups, a topic to which we shall return later in this section.

We now turn to the evidence, In one sense, it is easy to provide evidence that developed country capital-labor ratios are not the only alternatives available. A glance at any LDC industrial census which contains capital data will reveal capital-labor ratios that are usually a third of those in the U.S.;[14] and this is in spite of the fact that LDC rates of capacity utilization are usually below that found in the U.S., thus raising the LDC capital-labor ratios above what they would be with better capacity utilization (and hence more labor employed).[15] But a

believer in the superior efficiency of capital intensive methods would probably not be convinced by this kind of evidence. He or she might well argue that the LDC methods are inefficient (old, antiquated, improperly conceived) and/or that the over-manning of otherwise efficient capital equipment is occurring because of employment pressures in LDCs; protectionist policies in LDCs buffer these inefficient production units from more efficient competition from internal or external sources. Or, they might argue that the LDC methods are efficient only for the small size of the LDC markets and that larger volumes could be produced more efficiently with more capital intensive methods. This scale argument is one that we shall return to below. Accordingly, a more systematic investigation than just a casual perusal of LDC industrial censuses is needed. We shall discuss six kinds of evidence: (1) econometric investigations of the elasticity of substitution between labor and capital; (2) engineering or process analysis of substitution possibilities; (3) anecdotal evidence on substitution; (4) evidence concerning big firms versus small firms; (5) evidence on the use of used machinery; and (6) evidence concerning multinational corporations. Evidence on saving rates and hence the desirability of captial intensive methods, even if they are not efficient, will be reviewed. And the question of substituting more labor-intensive products in consumption will also be discussed.

(1) Econometric investigations of factor substitution

There have now been a large number of efforts to use LDC data, usually from industrial censuses, to try to measure the degree of substitutability between capital and labor. All of the efforts involve trying to measure the elasticity of substitution (i.e., the percentage

change in the capital-labor ratio in response to a change in the factor-price ratio) in a constant-elasticity-of-substitution production function involving capital and labor.[16] Since the CES production function is non-linear and cannot be estimated through ordinary least-squares estimation techniques and since data on capital is frequently not available or not considered reliable, an indirect method is used. If the logarithm of output per worker is regressed against the logarithm of the wage, the coefficient on the latter variable is an estimate of the elasticity of substitution.[17] Most studies use this form. (Some of the studies use a direct demand for labor/ formulation, in which labor is regressed against the wage, output, and other variables.) A few regress the ratio of output-capital ratio against the return to capital (both in logarithms) of the capital-labor ratio against the wage alone or the ratio of the wage to the return to capital (again in logarithms) to provide alternative estimates. These estimates have been made for the whole of manufacturing in single countries and for individual sectors within manufacturing, for both time series and cross-sections, and for cross-sections for sectors across different countries. Table 1 lists the countries, the empirical studies, and their dates of publication. As can be seen, a wide variety of countries have been covered by these studies.

It is difficult to characterize the results of these studies. The estimates of the elasticity of substitution are, with only a few exceptions, positive, indicating (if one accepts the methodology as valid) that efficient factor substitutability is possible and that the fixed proportions view of the world is incorrect. The estimates tend to clump between 0.5 and 1.2, but some studies find values appreciably above and

Table 1: Econometric Studies of the Elasticity of Substitution of Labor for Capital in LDCs

International cross-section

Boon (1969)
Bruton (1972a; 1972b)
Courtney and Leipziger (1974)
Daniels (1969)
Diaz-Alejandro (1973)

Argentina

Bruton (1972b)
Eriksson (1969)
Katz (1969)

Brazil

Bruton (1972b)
Eriksson (1969)
Tyler (1974)

Chile

Behrman (1972)
Bruton (1972b)

Colombia

Bruton (1972b)
Eriksson (1969)

Costa Rica

Eriksson (1969)

Dominican Republic

Bruton (1972b)

Egypt

Abed (1975)

Ghana

Leith (1974)
Roemer (1975)

Greece

Bruton (1972b)

India

Bruton (1972b)
Diwan and Damodar (1968)
Sethurman (1971)

Table 1 (continued)

Iran

Bruton (1972b)

Isreal

Bruton (1972b)

Jamaica

Tidrick (1970)
Williams (1974)

Kenya

Harris and Todaro (1969)
House (1973)
King (1972)
Maitha (1973)
Senga (1973)
Weeks (1974)

Korea

Bruton (1972b)

Malaysia

Bruton (1972b)

Mexico

Bruton (1972a)
Eriksson (1969)
Ibister (1971)
Witte (1973)

Nigeria

Oyelabi (1971)

Pakistan

Ahmed (1975)
Husain (1974)

Panama

Peru

Bruton (1972b)
Clague (1969)
Witte (1971)

Philippines

Bruton (1972b)
Sicat (1970)

Table 1 (continued)

Williamson (1971a)
Williamson (1971b)

Puerto Rico

Reynolds (1965)

Southern Rhodesia

Bruton (1972b)

Turkey

Demirigil (1971)

below these values. Cross-section studies tend to find higher elasticities than do time series studies. An elasticity above 1.0 implies that not only will a fall in wages induce an increase in employment (as labor is substituted for capital) but also that labor's share of output will increase. There will also be an extra effect from the added demand for the final product due to the fall in price induced by the decrease in wages, so that the total wage bill can increase even if the elasticity of substitution is below 1.0.

The problems -- in concepts, data, and econometric technique -- have been reviewed by Nelson (1968), O'Herlihy (1972), Morawetz (1974), Acharya (1974), Gaude (1975), and Morawetz (1976). The data are bad, the CES form may not be the correct one, the time series studies may not include lags properly, the profit maximization assumption may not be a good one, the assumption of competitive markets is surely not true, all firms may not be using the same technology, the cross-country studies may not use the correct exchange rates, the cross-section observations (especially across countries) may not be using comparable industries, the level of capacity utilization is usually not held constant, all labor and all capital are assumed to be uniform and to be the only factors of production, to name a few of the problems.[19] It is easy to be sceptical of the results. Pack (1972), for example, has argued that the time series regressions may well just be showing that value added per worker increases as capacity utilization increases and simple technological improvements occur over time and that wages increase as workers succeed in capturing some of that increase in productivity. Thus, rather than showing a causality between substitution away from labor and wages, the regressions may be showing a reverse causality between wages and increasing productivity.[20] Cross-section regressions

may be capturing a similar effect, as could the regressions using capital-labor ratios. And Moravetz (1976) has shown that there is little consistency among the cross-section studies in their rankings of common industries by estimated elasticity of substitution.

Leaving aside, then, the data and econometric problems which are always present to a greater or lesser degree in any empirical work, one's evaluation of the worth of these regressions does hinge crucially on how one views the causality between wages and capital-labor ratios. If one already believes that capital-labor ratios are efficiently flexible and that entrepreneurs do respond to factor price incentives, then the results of the regression do provide support for this view: making labor more expensive and capital cheaper tends to cause factor substitution towards greater capital intensity. On the other hand, if one believes that efficient factor proportions are more or less fixed (and that observed differences are largely due to random elements or to pressures to increase employment) and/or that wages respond to higher levels of productivity, then the regressions may not support the claim of substitutability. In this author's view, both effects are probably occurring, and the econometric evidence probably does give some support for the position that efficient labor-intensive alternatives for manufacturing exists. But this is probably more an act of faith than a hard conclusion from incontrovertible evidence. The believers in fixed proportions are unlikely to be convinced.

(2) Engineering or process analysis studies. In these kinds of studies, researchers investigate individual manufacturing processes or individual products. The investigators usually use engineering or other technical information to determine the inputs necessary to produce a given

volume of products (or to process a given volume of manufactured items). A principal part of the investigation is to see if there are alternative means of producing that same volume; i.e., if more workers and fewer machines (or, more usually, simpler and cheaper machines) can produce the same volume as fewer workers and more machines. This is, of course, the heart of the substitutability question.[21]

Table 2 lists the products and processes for which these studies have been done.[22] The list is not long, but an important result does emerge from these studies: Factor substitutability does seem to be quite possible, and the differences in factor ratios can be quite substantial. Timmer's (1975) study of rice milling and marketing systems found four efficient alternatives, of which the most capital intensive required $65,000 investment per worker and the most labor intensive required $700 per worker. The ECLA study of cotton textiles reported by UNIDO (1969, p. 44) showed a choice of efficient techniques ranging from $6,600 investment per worker to $21,500 investment per worker; Pack's (1974) study argues that the lower limit is closer to $1,100 per worker. Further, Pack (1974) was able to relate the efficient factor combinations observed in operation to the wage rates and returns on capital also present and thus to calculate elasticities of substitution. Of six industries observed, all had positive elasticities of substitution, and five were above 1.0.

Of course, not all technically efficient factor combinations, even labor intensive ones, would be economically efficient for LDCs. Just as a factor combination could be too capital intensive, it could also be too labor intensive. For example, suppose that a given volume of output can be produced with one worker and a $10,000 machine or by 100 workers

Table 2: Engineering and Process Analysis Studies Relevant to LDCs

Textiles

Bhalla (1964)
Hewavitharna (1970)
Pack (1974)
Pack (1975)
Sen (1972, Appendix C and D)
UNIDO (1969, p. 44)

Grain Milling

Bhalla (1965)
Pack (1974)
Timmer (1975)

Bicycles

Pack (1974)

Paints

Pack (1974)

Tires

Pack (1974)

Sugar Manufacturing

Baron (1975)
Hewavitharna (1970)
Pickett et. al. (1974)

Jute Processing

Cooper and Kaplinsky (1975)

Can Manufacture

Cooper, et. al. (1975)

Cement Blocks

Stewart (1975)

Coir

Hewavitharna (1970)

Metal Working Processes

Boon (1964; 1975)
Morse and Staley (1965, pp. 213-219)

Wood Working Processes

Boon (1964)

and a $9,900 machine. The latter combination is technically efficient, since it does involve a trade-off of labor and capital. But only if one was sure that the opportunity cost of labor was zero would the latter option make economic sense. In fact, however, in virtually all cases, at realistic opportunity cost wage and interest rates for LDCs, labor intensive or intermediate alternatives are economically sensible. LDCs do not appear to be limited to current developed country capital intensive methods.

There are some limits to these studies and some unanswered questions, however. First, the question of economies of scale and whether optimal factor proportions change with scale is examined only by Boon (1964, 1975) and by Stewart (1975). They find that there are appreciable economies of scale in many metal machining processes and in cement block making and that capital intensive methods are necessary to capture these economies. Thus, at low volumes, there are efficient alternatives, and relative wage and interest costs should determine the proper technique. As volumes increases, input levels grow more slowly, so that unit costs fall (for any wage and interest rate), but this happens to a greater degree for capital intensive processes. At very high volumes, the capital intensive processes dominate so that at any wage or interest rate it makes economic sense to choose the capital intensive processes. The lower the wage, however, the higher the volume at which it makes sense to switch from the labor intensive to the capital intensive processes.

Why economies of scale should favor capital intensive processes is unclear; it just seems to be a fact of technological nature for the particular processes investigated. To what extent can it be generalized?

Most of the investigators of product technology do not mention it, and it seems likely that this is a phenomenon restricted in significance to only some of the processes that go into manufacturing a product, like metal finishing, and flow processes involving liquids, pipes, and containers like petroleum refining and chemical production. The importance of setting-up costs for a production run or of the surface area and volume relationship of containers[23] dominate here. For other manufacturing processes, scale effects seem likely to be much less important. (This appears especially true of the peripheral activities mentioned in the next section.) Clearly, though, much more needs to be known about the relationship between scale and factor substitutability.

For a product that does embody significant scale effects, LDCs face a dilemma.[24] The small market LDC can achieve appropriate factor proportions but has high unit costs (but, it must be emphasized, the LDC would have yet higher unit costs if it switched to the capital intensive method); the large market LDC has lower unit costs but high capital intensity.[25] Only research leading to new technologies that would decrease the importance of scale effects or have them apply equally to labor intensive methods offers a way out of this dilemma.

A second open question in these studies is the problem of quality. Are capital intensive processes necessary to ensure high quality? Stewart (1975) argues that this is the case for cement blocks. The other studies though, either claim that quality need not be affected by technique or neglect to mention the problem. As noted above, other observers, like Baranson (1967; 1969b, chs. 2 and 3, 1972) and Strassmann (1968, pp. 93-102, 155-157) argue that, particularly in metal finishing processes, machines

can substitute for skilled labor and foreman supervision in ensuring a high, uniform quality standard. Again, we need to know more in this area.

Finally, on this last point, there are other inputs into the production process, and the process studies do not tell us enough about them. Baron (1975) and Pack (1974) do account for the differential efficiency in the utilization of raw materials of different techniques. Unfortunately, it is difficult to tell if this is a serious problem generally. Further, is the argument that mechanization is an efficient substitute for management supervision skills valid? Unfortunately, there is only one piece of quantitative evidence on this point. Clague's (1970) study showed that the overall efficiency of Peruvian industries relative to that of comparable U.S. industries increased as capital intensity increased; machine paced processes seem to offer less latitude for labor inefficiency.[26] The engineering and process studies have not thus far been able to quantify this, and so it must remain, with the exception of Clague's study, largely an open question. Pack (1972; 1976) argues that good management is also needed in order to recognize the possibilities for labor-capital substitution and to do the necessary innovations to adapt equipment rather than just accept completely the sales pitch of the traveling capital goods salesman from the U.S., Europe, or Japan. But Pack (1975) reminds us that high levels of mechanization will require the repair skills necessary to repair the complex modern machinery, and these are usually as scarce in LDCs as the management skills that the machines are supposed to replace. The repair skills to handle simpler machinery, however, usuallyare in greater supply.

In all, the engineering and process analysis studies do provide powerful demonstrations of the feasibility of labor intensive methods and are probably more convincing than the econometric studies of the previous section, but there are still the difficult questions of scale, quality, and skill substitution.

(3) Anecdotal evidence. Under this category we group studies that report examples of labor-capital substitution but do not offer precisely quantified estimates of the frontier of efficient combination in the way that the engineering studies do. These reports can nevertheless offer useful insights in the production processes.

Fei and Ranis (1972; 1975) and Ranis (1957; 1971; 1973; 1974; 1975) have documented a number of ways in which labor could be efficiently substituted for capital. During Japan's early industrialization, when wages were comparatively low, machinery in textiles and other industries were run faster and more intensively (extra shifts); this meant more frequent halts for repair, but repair was a labor intensive activity. The overall effect was greater labor intensity and greater efficiency in the use of all resources. Thus, even in processes in which mechanization was necessary for quality reasons, double and triple shifts greatly decreased the overall capital-labor ratio. Greater use was made of older, used equipment from the West. Raw material inputs were modified so that more labor intensive processes could be used. Ranis reports that similar capital-stretching, labor intensive techniques are currently being used in Korea and Taiwan in textiles, electronics, woodworking, and other industries. He further points out that even for products in which there may be technical rigidity in some main production processes, there are always

peripheral processes like materials handling and packaging, which can be done efficiently with labor intensive methods, so that the overall production of the product still has scope for labor-capital substitution.

Similarly, Pack (1972;1976) reports examples of labor-capital substitution in consumer goods manufacturing in Kenya. He too notes the possibility of factor substitution in peripheral activities, but also notes quality problems: human handling of fruit inputs into food manufacturing may lead to higher rates of spoilage or breakage. He also notes s scale sensitive process: container filling. At high rates of volume, some container filling processes would be worth automating regardless of wage levels.

Other reports of LDC production processes that are more labor intensive than those of developed countries include Strassman (1967; 1968; ch. 6), Baerresen (1971), Sharpston (1973), ILO (1972b, pp. 141, 446-450), Wells (1973), Boon (1975), Baranson (1967, pp. 59-62; 1969, pp. 4-7), Mason (1970), and Armas (1973). But are the adaptations efficient? In virtually all cases, the researchers report that the greater labor intensity has taken place in response to the lower volumes and/or the lower wage of the LDCs. This kind of response (as opposed to, say, a report that greater labor intensity seems to have occurred at random) does tend to support the notion that these are efficient adaptations. Also, Ranis' examples include firms that were facing substantial competition, either internally or in export markets; again, there is a presumption that this would tend to be forcing efficient adaptations. Finally, Ranis, Pack, the ILO, and Strassmann connect the adaptations with good, flexible management; again this argues for

efficient adaptation.

The anecdotal evidence then, points in the same direction as the earlier evidence: greater labor intensity is not only feasible but is in fact occurring in some LDCs. It does, however, seem to be closely tied to good management.

(4) Big firms versus small firms. It is widely acknowledged that small firms are more labor intensive than large firms.[27] Many claim that the small firms have adopted this greater labor intensity in response to the different factor prices that they face compared to large firms: cheaper labor and more expensive capital. This kind of response, they argue, shows that it is an efficient adaptation and hence that efficient factor substitution is quite feasible.

But are the small firms efficient? A counter-argument would run as follows: The small firms may have lower capital-labor ratios, but they are inefficient, in the sense that they use more labor and more capital per unit of output than do large firms. They are still able to sell goods in the same market as the big firms, though, because their wage costs are so much lower; i.e., because the labor markets are imperfect.[28] Hence, the greater labor intensity of the small firms is not necessarily an efficient adaptation.

The output-capital ratio of the small firms compared to the large firms is critical to deciding this point. The evidence is mixed: Ranis (1962a) finds that small firms in Pakistan had higher capital output ratios than large firms; Mehta (1969) finds the same to be true for India, as does Marsden (1969) for a number of countries. But Dhar and Lydall (1961) find the opposite to be true for India, as does Sandesara (1966; 1969).

Unfortunately, truly valid comparisions between large and small firms are very difficult to construct. Not only must the same final product be produced by both firms, but they must be vertically integrated to the same extent. For example, suppose that large firms produce more of their own inputs or do more of their own distribution than do smaller firms. These extra activities probably involve different factor proportions than the main production processes that are being compared. Thus, we could observe different capital-labor ratios and different output-capital ratios between large and small, even if the main production processes were identical, and might mistakenly conclude that these indicated differences in efficiency. It does not appear that any of the studies cited above have tried to correct for this problem.

Overall, then, we can learn little from the comparisons between large and small firms. The latter are surely more labor intensive, but we simply cannot conclude anything about their efficiency. If labor and product markets were competitive, the mere survival of the small firms would strongly imply that they were efficient. But, since neither set of markets qualifies as competitive, little can be decided.

(5) Used machinery. Second-hand machinery is frequently recommended as a way for LDCs to reduce capital-labor ratios. The theoretical argument runs as follows:[29] Profit maximizing firms should find it worthwhile to replace existing machinery with new machinery either (a) when there is enough technological imporvement so that the average total costs of output produced by the new machines are below the marginal costs of output produced by old machines or (b) in the absence of technological improvement, when future discounted maintenance costs exceed the price of the new machines plus their future discounted maintenance costs. In both

cases, replacement depends on comparing one set of costs that have a heavy labor weight with another set of costs that have a heavy capital element. Thus, a high wage economy will find it economically rational to replace machinery much sooner than would a low wage economy, and low wage LDCs should find worthwhile the purchase of used machines that developed countries find marginal. In the developed country, if there is an active market in used machinery, the price of the used machine would have to fall by enough . . . . for a developed country buyer to find it worthwhile to consider the used machine as an economic alternative to the new machine. At that price, the LDC buyer will surely find the machine more worthwhile (except for added transportation costs), because of the latter's lower wage costs.[30]

The counter argument (often presented by those who believe in fixed proportions), is that good markets in used machines do not exist, used machines are a very risky proposition, spare parts may not be available, or the machinery is so technologically obsolete that the use of the machines is inefficient compared to new machines.

What is the evidence? First, it should be noted that organized markets in used machinery are present in the developed countries. Brokers, catalogues, and trade associations of used machinery dealers do exist. Second, there is a fair amount of evidence that used machinery is employed efficiently in LDCs: Cooper and Kaplinsky (1975) in jute processing; Pack (1975) in cotton textiles; Boon (1975) in engine machining; James (1973) in paper manufacture; Armas (1973) in pineapple canning; and Strassmann (1968, ch. 6) for a number of Mexican industries. Pack (1976) in a number of consumer goods industries in Kenya; Cooper and Kaplinsky do stress the risk element in buying used machines; it takes special skills to be able to tell which ones are the "lemons," and manufacturers' warranties will

no longer apply. Indeed, all of the studies stress the need for good management and engineering skills as a necessary adjunct to the proper choosing, adaptation, and use of second-hand machinery.

There is one additional example of an industry in which active second-hand markets exist in developed countries, spare parts are available, and technological change has not been rapid: motor vehicles. There constantly are large stock of used cars and trucks available for sale in the U.S. and Europe. It is well known that, particularly for cars, prices depreciate faster than pure utilitarian usage considerations would dictate. Spare parts are usually quite available. And technological change since World War II has been quite slow.[31] It would appear that many LDCs would do well to forego importing new vehicles on attempting the domestic production of these vehicles and instead to buy and import large quantities of used vehicles (Meyer, 1966). Repair requirements would be greater for a fleet of vehicles bought used rather than new, but there are skills that are present in most LDCs and probably should be further encouraged. Parts, if not available, could be manufactured locally. Both domestic and foreign exchange resources would be saved for better uses, and effective capital-labor ratios in transportation would be lowered.

Again, the evidence on used machinery does show the possibilities of lower capital-labor ratios.

(6) Multinational Corporations (MNCs). The MNCs are frequently pictured as the special villans of the appropriate technology effort. They are, so the argument goes (Vaitsos, 1975; Stewart, 1973a, 1973b; Streeten, 1972b, 1973), tied to their capital intensive technology in the developed countries. That is what they are familiar with; that is what their product quality and trademark image is frequently based on. It is

frequently too risky and costly for them to try to change their technology for LDC conditions. They ignore the possibilities of using local raw materials inputs. And, even if they were considering adaptations, they frequently pay higher wages than do locally-owned firms and they can obtain their capital abroad at cheaper rates, so they would have less incentive to adapt.

The counter argument is presented by Pack (1972; 1976). As noted above, he argues that good management appears to be necessary to recognize and utilize the possibilitiss of labor-capital substitution. And the MNCs frequently have the best management around. Even if they pay higher wages than local firms, their wages are still considerable lower than those in the home country, and thus there is a strong incentive for adaptation.

What is the evidence? Here we must be very careful in evaluating it. A number of interview and questionaire surveys of MNCs, by Reuber (1973), Baranson (1971), Yeoman (1968), Hughes and Seng (1969), and Gregory and Reynolds (1965) have concluded that only a modest amount of technological adaptation has taken place, and that has been mostly in response to lower volumes, not local factor costs. This evidence has been widely cited by those who see the MNCs as villains.

But there is an interesting paragraph in Boon (1975, p. 270) that is worth recounting at some length. He describes an interview at an engine plant owned by an MNC in Mexico. At the beginning of the interview, the management assures Boon that the Mexican plant uses exactly the same technology as that used in the parent plant in the developed country. But as the interview proceeds and Boon tours the factory, it becomes clear that in many respects the factor proportions are different. The main

machinery processes are automated, but second-hand equipment is used. And all of the auxiliary processes, like packaging, handling, transporting and storing, are done much more labor intensively. Perhaps interviewers get told what the interviewees think they wish to hear, or what the interviewees wish to believe!

Contrary to these surveys, it appears that any researcher who sticks his head into an MNC facility in an LDC and looks around is likely to find substantial adaptations of capital-labor ratios, particularly in auxiliary processes. This is the case for Boon (1975), Pack (1972, 1976), Barenson (1967, pp 59-62); Strassmann (1968, chs. 5 and 6), Mason (1970), ILO (1972b, pp. 446-450), Wells (1973), and Armas (1973), Ranis (1971, 1973, 1974, 1975), Helleiner (1973a; 1973b), and Baerresen (1971) find MNCs adapting to labor-intensive processes for export processes. Not all MNCs adapt. Pack (1972) does cite an example of a home office insisting that more capital-intensive processes be maintained, even though the branch manager recognizes that the labor intensive methods would be more profitable. And not all of the MNCs in Strassmann's sample adapted their technology. But a higher fraction of the MNCs in Strassmann's sample adapted their technology than did locally owned firms. And a higher fraction were buying and using second-hand machinery. Again, similarly to Pack's argument, the importance of good flexible management possessed by MNCs is stressed by Strassmann and by the ILO (1972b) mission to Kenya.

It appears, then, that both locally controlled firms and MNCs can and do adapt their factor proportions. But which group is more likely to adopt the more labor-intensive methods? In examining comparative evidence, it is necessary to exclude economy-wide comparisons. Here, we will always

find that MNCs are more capital intensive than locally controlled firms. This is to be expected, since the MNCs do have a comparative advantage in capital intensive products. The critical question concerns comparisons within an industry in which both groups are present. Strassmann, Pack, and the ILO mission to Kenya all find the MNCs to be more labor intensive; they explain this on good management grounds. Mason (1970; 1973) finds that for a group of matched pairs of firms, U.S. controlled firms tend to be somewhat more capital-intensive than locally owned Philippino or Colombian firms; he explains this on the grounds that the U.S. firms pay higher wages and have access to cheaper capital. Radhu (1973a) also finds foreign firms to be more capital intensive than locally owned Pakistani firms. But Cohen (1973; 1975) finds no significant differences between foreign and Korean firms producing for export markets. The evidence is clearly mixed.

Although the MNCs may not be the heroes of appropriate technology, they appear to be far from the villains that many make them out to be. They have the management expertise, and they are frequently willing to use it to adapt to labor intensive processes. Again, there is adequate evidence of factor substitutability.

(7) Factor proportions and saving rates. An argument cited earlier in favor of capital intensive methods is that they would raise the income share of capital owners, who are supposed to have higher rates of saving and reinvestment than do workers; the pace of industrialization would thereby be quickened. This kind of argument, of course, presupposes that government taxation of labor incomes for saving purposes is not feasible. But, ignoring

this, what do we know about savings rates?

The evidence reviewed by Mikesell and Zinser (1973) does indicate that saving out of labor income is very low; the marginal propensity to save rises with income, and the saving rate out of profits is high. But Oshima (1971) argues that added income to low-wage workers might reduce the dis-saving of many. If we turn to the saving rates of firms of different capital intensities, Ranis (1962b) provides evidence that medium size (less capital intensive) firms have higher saving and reinvestment rates per unit of output than do large firms. Appavadharrlu (1974) argues that small firms in India have higher saving rates than large firms.

The evidence, then, is somewhat mixed. And, given the possibility of government taxation as a form of saving, the income distribution, saving, and reinvestment argument appears to be a weak reed on which the case for capital intensity might rest.

(8) Product substitution. Some researchers have argued that, in addition to the wrong factor proportions being used, the wrong products are being consumed (Streeten, 1972c; Stewart, 1973b; 1974); Hughes, 1974), Consumer durables like automobiles, washing machines, and air conditioners have capital intensive production technologies. More appropriate products and services, like bicycles, launderers, and coolers would be more labor intensive. (We will leave the issue of the development of new products for LDCs for Section V.) Frequently it is claimed that this is the result of an inappropriate income distribution in LDCs -- too heavily skewed toward the rich -- and that a radical redistribution of income is necessary.

Though this last suggestion may be recommended on ethical grounds, it appears that income redistribution would likely have only a tiny effect on employment. A number of macro-economic models of LDCs, reviewed by Morawitz (1974) and Cline (1975), all come to that conclusion.[32]

A less radical alternative would be simply to levy excise taxes on capital intensive goods which have labor intensive substitutes. Indonesia (Sadli, 1974) taxes "modern" manufactured cigarettes more heavily than traditional kretek clove cigarettes. But India (Baron, 1975) tries to encourage the consumption of capital intensive white sugar (as compared to the less refined gur) by keeping its price low.[33]

Another way of encouraging the production of appropriate products is to orient the economy toward exports (Ranis 1971; 1973; 1974; 1975; Fei and Ranis, 1975; Helleiner, 1973a; 1973b; Porter, 1972; Balassa 1971; Baerresen, 1971; Sharpston, 1975; Little et al., 1970). Here, labor-intensive goods and processes will have a comparative advantage in world markets and hence will be the natural choice for LDCs. This is the path that the "success stories" of East and Southeast Asia -- Korea, Taiwan, Hong Kong, and Singapore -- and, to a lesser extent, Colombia, Brazil, and Mexico have followed.

(9) A summary on factor proportions. This section has summarized the available literature on the possibilities of labor-capital substitution in LDC manufacturing. Each sub-section has presented one aspect of the evidence. By itself, each sub-section may not appear entirely convincing. But together they do paint a rather impressive picture. There do seem to be plenty of opportunities for more labor intensive methods to be used. And

there do seem to be opportunities for a more appropriate product mix. The ranges of choice are far from complete on both the production and product sides. The economist's smoothly curved production isoquant is rarely present. It is the task of research and development to increase the range of choice, a topic we shall tackle in Section V. But the claim of fixed coefficients simply does not offer a satisfactory explanation for the absence of appropriate factor proportions in most LDCs.

IV. The Causes of Inappropriate Factor Proportions

The evidence of Section III suggests that the possibilities for labor intensive production methods are much greater than the current practice in most LDCs. If fixed factor proportions are not the reason for LDC capital intensity, what explanations can be offered?

First, the relative prices of capital and labor are frequently badly out of line with their true social worth: a wide variety of government policies have made capital artificially cheap in capital-short economies, while labor has been made artificially expensive in many of these same economies (Little et al, 1970). Capital is made cheaper through government subsidized low interest loans, favorable exchange rates or low tariffs for imported capital goods, tax holidays on new investments, and accelerated depreciation on capital goods.[34] Labor in urban manufacturing has been made more expensive through minimum wage legislation, mandated fringe benefits, restrictions on the ability to lay off workers, and government encouraged union pressures.[35] These labor provisions are most likely to be enforced in the government sector, in large firms, and in MNCs. As we argued earlier, they are a major factor in encouraging high urban unemployment. Real urban wages are frequently two or more times rural wages.[36] In a number of countries, the relative prices, distortion of labor and capital, rather than getting better, has become worse during the years since the Second World War. Witte (1973) estimates that the wage/capital-rental ratio for all of Mexican manufacturing rose from an index of 100 in 1945 to 280 in 1964; for Peru, the price ratio for a number of industries rose from 100 in 1958 to a range of 190-270. Roemer (1975) reports that the same ratio in Ghana rose from 100 to 124 in 1966 (but subsequently fell to

90 in 1970). Krueger (1974, p. 235) reports an appreciable rise in Turkey for the period 1955-1970. In a contrary case, Williamson (1971) reports a falling ratio in the Philippines for 1955-1966; this is confirmed by Hicks and McNicholl (1971) and by Baldwin (1974, p. 148). But generally the pattern reported is rising real wages in manufacturing in most LDC countries, while capital remains cheap or becomes cheaper (Smith, 1969; Knight, 1975; Berg, 1971; Gregory, 1974).

The rising real wages in LDC manufacturing sometimes receive two defenses; both should be put to rest. First, it is argued that wages should rise with the increases in productivity in manufacturing. Besides mixing cause with effect, this argument is wholly inappropriate for an economy with widespread un- and under-employment. As long as there is substitutability, greater capital shallowing should be encouraged through low wages; only when labor grows scarce should real wages rise in line with rising productivity. Second, it is argued that in a world of monopolistic MNCs which escape LDC taxes through internal transfer pricing vis-a-vis the parent company, high wages may be the only way that the LDC can capture some of the profits. But the obvious solution to this is to improve government taxation and customs procedures and to reduce the MNC's monopoly power by introducing more competition (via imports, if necessary) into the domestic economy in which the MNC sells or by opening up for wider bidding the extraction and export concession that the MNC has. Using wages to try to capture those profits is a distinctly inferior and potentially quite harmful policy.

The cheap capital and high wages policies have laudable goals: to encourage investment and to raise worker incomes. But their

inevitable result is to encourage entrepreneurs to substitute away from labor and toward capital intensive processes. The econometric studies of the elasticity of substitution, if they are to be believed, certainly point in this direction. The engineering and process analysis studies, especially Pack's (1974), also tell the same story. And much of the anecdotal literature, analysis of small firms, and discussion of MNC adaptations do link changes in capital-labor ratios to relative factor prices.

Further, inappropriate factor prices make capital intensive goods cheaper and labor intensive goods more expensive, thus discouraging consumption of the latter. Not only are the wrong processes encouraged, but the wrong products are also encouraged (Cooper, 1972).

But factor prices do not seem to offer a complete explanation of the existence of inappropriate factor proportions. A second reason seems to be the strong tendency for entrepreneurs/engineers to think and especially in terms of developed country mechanized technology as the ideal, regardless of factor prices. The confusion between high labor productivity and efficiency enters here. If markets are non-competitive, entrepreneurs seem willing to sacrifice some of their potential monopoly profits in order to achieve this goal of mechanization. Wells (1973) has labeled this the phenomenon of "engineering man." The argument also appears in Bruton (1973), Pickett et al (1974), and Ranis (1974). This appears to be a widely held notion. But there has been only one attempt formally to test the proposition. White (1976?) found that greater competition in Pakistani product markets forced industrialists to adopt more labor-intensive methods relative to the U.S. "ideal"; industrialists in less competitive markets were freer to pursue

their engineering goals.

Third, even in instances in which firms might be interested in more labor intensive methods and those methods do exist, information about them is frequently difficult to obtain. Search is costly, the firms are familiar with the capital-intensive processes, and the absence of competition may reduce the incentive to search. Or even with search, they may simply fail to find out about the labor intensive methods.[37]

Fourth, not all MNCs adapt their technologies. There are plenty of "engineering men" in MNCs, and, if permitted by non-competitive markets, they too will mechanize beyond socially optimal levels.

Fifth, inappropriate government policies, beyond the labor and capital pricing policies and the failure to encourage competition mentioned above, are another contributing cause. Badly conceived public projects, like the petrochemical complex cited by Morawetz (1974), are a bad use of resources and surely do not provide a good example to the private sector. The mystique of high productivity and modernity pervades the public sector as much as it does the private sector. Other poor policies include a frequent negative attitude toward the import of used machinery and used vehicles, sometimes taking the form of outright bans.[38] This is based on the belief that used machines are inferior and private entrepreneurs are mistaken in their purchases or that used machinery may be an easier vehicle for smuggling (through over-invoicing to smuggle funds out of the country or under-invoicing to reduce tariff duties, since the customs officials may be less familiar with the true value of the machinery). As argued above, such policies are sacrificing potential major improvements in labor-capital ratios.[39] And the unwillingness to tax or otherwise discourage the consumption of capital-intensive

consumer goods and the unwillingness of many governments to encourage the development of export markets for manufactured goods further push their economies toward capital intensive methods.

In short, LDC government policies can go a long way in explaining the inappropriate factor proportions observed.

V. The Evidence on Research and Development in LDCs

Though plenty of opportunities for more appropriate factor proportions exist in LDC, the range of choice is far from complete, and in many instances there is a serious need to develop new processes and products for LDCs that will be more labor intensive and, of course, that will increase the overall productivity of all factors generally.[40] This is technological progress, with research and development as the main generating agent. Unfortunately, technological progress and R&D are only imperfectly understood in the developed countries, and the data is still poor and spotty. There have been recent surveys by Kennedy and Thirwell (1972) and Kamien and Schwartz (1975). Much less is known about this area in LDCs.

First, a few clarifying remarks. Improved products and processes are the desired end result. Unfortunately, it is frequently difficult to quantify these measures properly at the micro level for testing hypotheses. Sometimes, patents are used as a proxy for the desired measures, or lists of inventions are used. More frequently, R&D personnel are used instead. But it must be remembered that these are <u>inputs</u> into the technological progress process, whereas we are really interested in the output of the process. By measuring and testing hypotheses on inputs, we must be assuming a fairly fixed relationship between inputs and outputs. Though there is evidence of a positive relationship between these inputs and outputs in the U.S., evidence on whether this is linear or not and what other factors influence it is nonexistent.[42]

There are two major hypotheses concerning technological progress and R&D. One is the Schumpeterian hypothesis that large absolute size of firm and market power are necessary to generate R&D. The

former is necessary because of economies of scale in the R&D process itself (e.g., a laboratory or workshop may have a minimum efficient size); the latter because market imperfections are necessary to generate the funds for investing in R&D and absorbing the risks of R&D and to overcome the problem of competition stealing and copying new ideas and thus making investment in them unprofitable in the first place. A contrary set of hypotheses argues that invention and innovation is still a creative process best suited to individual or small group situations and that the best spur to invention and innovation is at least a moderately competitive market in which firms fear that if they do not innovate some other firm will do so instead, to the first firm's detriment.

There have been extensive testing of these hypotheses. Size does seem to matter in generating more R&D or patents as a percentage of sales, but only up to a point. This point seems to vary by industry. The largest firms in these industries rarely do proportionally the most R&D. But there is the problem of under-reporting by small firms (and probably over-reporting by large firms, since R&D has become a prestige area), and Jewkes et al (1969) offer plenty of stories of major inventions that have been developed by individuals or small groups. The case for market power is much weaker; some studies find that it matters, others that it does not.

Let us now turn our attention to R&D in the LDCs. Unfortunately, so much less is known that generally writers on the subject are content if they can just quantify R&D expenditures; these have been only a very small handful of empirical tests of hypotheses.[43] The Sussex Group (1970) has estimated that LDCs do only 2% of all of the R&D conducted in the non-Communist world. Frankena (1974, p. 256)

estimates that Indian manufacturing firms spend only 0.1-0.2°/o of sales on R&D; the ILO (1972b, p. 148) report on Kenya gives a similar figure for Kenyan manufacturing. Herrera (1972) estimates that Latin America spends only 0.2°/o of GNP on R&D.. By contrast in the U.S., 3°/o of GNP is spent on R&D, and manufacturing industries on average spend 2°/o of sales from their own finances on R&D (Scherer, p. 349). Katz (1973), in one of the few quantitative studies of LDC R&D, found that the R&D expenditures as a percentage of sales of Argentine firms in nine industries were only a fifth of the relative amounts spent by domestic U.S. firms in the same industries.

The reasons for the low levels of spending are many: low levels of income; shortages of trained personnel; the small sizes of firms in LDCs (Katz, 1973); the ready availability of developed country technology and the low risks involved in transferring it intact rather than trying to adapt it; the absence of competitive pressures to innovate (Frankena, 1974; Baranson, 1974); and the practice of MNCs, if they do any R&D relevant to LDCs, mostly to do it in their home countries.[44]

As a consequence of the low levels of R&D, many argue (Stewart, 1972; 1974; Streeten, 1972c; Vaitsos, 1975), labor intensive processes are not developed for LDCs, and new products that would be more labor intensive and would be more aimed at the mass markets of low income consumers are not developed. Further, there is probably a close connection between process adaptation and product adaptation. In many cases adaptation of the processes requires product adaptation, to make fine tolerances less critical and frequently to lower the general quality of the product. The MNCs come in for their share of criticism here, since their reputations are frequently based on the quality of their products and they are

reluctant to tamper with that image.

Still, it is instructive to remember that some invention, innovation, and adaptation does occur in LDCs. The anecdotes in Section III were all largely instances of firms innovating: taking developed country machinery or processes and altering them to suit the LDC conditions. Three stories of individual innovations in LDCs--Sansom (1969) on a lift pump in Vietnam, Dommen (1975) on a bamboo tube well in India, and James (1973) on paper manufacture in Mexico--would certainly fit the patterns described in Jewkes et al (1969), Strassmann (1967; 1968, pp. 172-173, ch. 7) provides examples of product and processes developed in Mexico. Khan (1974) and Duff and Khan (1974) describe innovations in the design and manufacture of small-scale agricultural implements at the International Rice Research Institute. Even a few of the MNCs have research operations in LDCs and do adapt items like cars and tires to local conditions and currently seem to be interested in providing new high nutrition food products for LDCs (USAID, 1972).

But, clearly the flow of new products and processes that are appropriate for LDCs is not fast enough. Efforts should be made to encourage more R&D and, of course, to make sure that it is aimed at the right targets. Here, the question of incentives arises again. First, Strassmann (1970; 1971) and Greene and Strassmann (1971) note that the innovations in Latin American construction methods tended to be labor saving, and they relate this to rising real wages for construction workers. They also note that the labor-saving innovations tend to be adopted more slowly where real wages are lower. Second, Pack (1972; 1976) argues that labor-intensive methods may encourage more rapid technological progress, since new processes do not have to be embedded in expensive capital goods. Third,

Cooper (1974) notes the connection between the research and consulting of the Engineering Faculty at the University of Nairobi and their teaching. The government sector in Kenya wants capital-intensive "modern" methods on its projects; it wants to hire engineering graduates and faculty consultants who know these methods. Therefore the faculty must teach these methods and do most of their research on projects relating to them. Fourth, research on appropriate products will not be encouraged if inappropriate factor prices or exchange rates make domestic production unprofitable. One report (USAID, 1972) gives the example of a Pakistani research institute developing a new pesticide, but the report's author is then puzzled as to why the institute could get no entrepreneur interested in producing it. Small wonder, when Pakistan had a badly over-valued exchange rate and pesticides could come in duty free. Fifth, Frankena (1974) notes that India's foreign exchange control regime meant that there was less competitive pressure to design new products and processes; Baranson (1974) has similarly argued that Brazilian firms do little R&D because of the absence of competitive pressures. Frankena also points out that the control regime encouraged dependence on foreign technology, since a domestic firm with a foreign collaborator to provide foreign exchange could more easily get government approval for new projects. Finally, prestige factors also play a part in assessing what kind of R&D is worth encouraging. Katz (1973), for example, describes the research potential of firms in Argentina's electrical goods industry and writes in disparaging terms of the small firms that make simple transistor radios for the domestic market. Katz's views would probably be shared by government officials deciding on the allocation of research funds. Yet these firms may have made the best

adaptations of product and process for the bulk of the market.

Research institutes in LDCs are frequently seen as a way of encouraging appropriate R&D and of transmitting new and existing knowledge of techniques to LDC firms, especially small firms. There are plenty of examples of successful research institutes (the Korean Institute of Science and Technology, IMIT, IRRI, the wheat research institute in Mexico, the Madras Leather Institute), but also of institutes which are not (Strassmann, 1967; 1968, ch. 7; Stewart, 1974; USAID, 1972; Khan, 1974; Duff and Khan, 1974). The leadership of these institutes appears to be critical to their success. The decision by an institute to solicit contracts to solve problems and to do applied research is also important.[45] The contrary decision to do basic research and try for published papers in developed country learned journals will mean another research institute spinning its wheels. Finally, there are problems of confidentiality of information, since many firms fear that publicly sponsored research institutes will reveal confidential information to the tax authorities or politicians (Strassmann, 1968, pp. 43-48).

Pressuring the MNCs to do more R&D in the LDCs is another approach. Countries might make this a condition of entry by the MNC. Again, appropriate factor prices and product taxation would certainly encourage this process, as would more competition in product markets. Indeed, much of the problem that LDCs face in paying too much for the transfer of technology (through excessive royalties, improper transfer prices on inputs, etc.) would disappear with a combination of tougher bargaining and a pro-competitive (via import competition) policy that would reduce the potential profits that the MNCs could siphon away. The picture (Barnett and Mueller, 1975; Streeten, 1972b; 1973) that is frequently described of helpless LDCs at the mercy of

a handful of monopolistic MNCs is largely false. Alternative suppliers of technology to achieve similar ends almost always exist, and LDC policy makers can and should be able to take advantage of this.[46] Even in the world automobile industry, which exhibits tight oligopoly in domestic production in every developed country, there are more than a dozen producers capable of LDC production.

Finally, the question of patents in LDCs combines the problem of incentives and MNCs. Patents provide a property right in an idea and thereby encourage the investment of resources (R&D) in the production of new ideas that would otherwise be copied at low or zero cost. But they do convey a monopoly on the idea in the process. In LDCs the vast majority of patents are granted to foreigners (Vaitsos, 1972; O'Brien, 1974), and only a tiny fraction of them are ever used in the LDC. Essentially, the patents largely protect foreign inventions from being copied domestically rather than encourage domestic invention. But the patent system does encourage some MNCs to produce in LDCs, which they otherwise would not do if they could not protect their products and processes (Penrose, 1974). The publication of the patent in the developed country reveals the basic invention (Grundmann). But there is usually non-patentable proprietary confidential information that is necessary to make the invention work. This is what the MNC is frequently bringing to the LDC, and the protection of the patent also protests this proprietary knowledge. The critical question is whether a broad patent system that possibly encourages some domestic invention and some MNC investment but that also prevents domestic firms from using foreign owned patented inventions that the foreigners are not using is worthwhile. There is simply no evidence to support strongly any conclusions.

It is probably the case that a more selective system--e.g., one that voided foreign held patents after a period of domestic non-use --would be more worthwhile.[47]

For R&D in LDCs, then, though the picture is far from bleak, it is also far from rosy. Though some R&D is done, more is needed. But, again, incentives are important, and policies should be shaped carefully. It is too easy to throw away large sums of money on ill-conceived R&D.

VI. Conclusions

The evidence summarized in this paper does suggest strongly that greater labor intensity in LDC manufacturing is feasible and would be efficient. The possibilities are not unlimited; there is still plenty of room for the discovery of intermediate technologies through well-directed R&D. But a view that LDCs are currently condemned to high capital-labor ratios, because there are no efficient alternatives, simply is not consistent with the evidence.

The evidence also suggest that incentives matter. Appropriate factor prices are an important spur to the discovery and profitable use of appropriate factor proportions and appropriate products. Effective competition in product markets can also provide an important push in the right direction, by leaving less scope for engineering instincts to dominate efficient factor use.

Large gaps, however, still remain in our knowledge of appropriate factor use. The micro studies of efficient alternative factor proportions have only been completed for a small handful of industries. It would be reassuring to have many more studies showing that alternatives exist. Also, these kinds of studies could profitably be focused on the auxiliary handling, packaging, transporting, and storage processes that figure prominently in the anecdotal examples of substitutability; again, it would be reassuring to have more precise estimates here. Further, we still do not understand very well the connection between scale effects and mechanization, nor the extent to which it is a genuine problem. And the connection between quality standards and mechanization and the extent to which mechanization serves as a substitute for skilled processing labor

and/or management supervisory skills are still largely unknown; most evidence here is still qualitative rather than quantitative. (But, it cannot be emphasized too frequently that better utilization of existing capacity--multiple shift work in particular--can greatly increase the overall labor-capital ratios of apparently capital intensive processes. and/export markets that can supplement small internal markets so as to achieve possible scale economies.) Finally, the connection between good management and the ability to recognize and utilize the opportunities for labor-capital substitution needs much greater exploration.

The conclusions of this paper point directly to a number of policy implications. First, the establishment of proper factor prices is terrifically important. This has been a familiar refrain from economists over the past ten years, but it can still bear repeating. The subsidies to capital use must be ended; an important part of this would be the replacement of exchange control and over-valued exchange rates with a realistic exchange rate. If wages in the urban modern sector cannot be decreased, at least their rates of increase must be substantially moderated in many countries. This is difficult to advocate, since the wages are low by developed country standards; but they are high by comparison with the incomes of the bulk of the remaining population in the LDCs, and the wage increases in the urban sector must necessarily reduce the potential for improving the incomes of the poorer majority. If these policies of altering relative factor prices are combined with pro-competitive policies and more effective taxation policies, they need not imply a decrease in labor's share of (or claim on) output relative to capital's share. Rather, the effect will largely be an increase in the government's share (and possibly lower product prices because of the

pro-competitive policies); these extra government revenues can (hopefully) be spent on welfare increasing activities.

With respect to the small firm/large firm problem, efforts to provide special facilities or subsidies to small firms are probably unwise. It is easy to waste funds on unproductive projects in this area,[48] and it would be a serious mistake to compound the current incentive errors by subsidizing capital for small firms. Rather, it would probably be quite adequate simply to give small firms unhindered access to resources; i.e., to stop current discrimination against small firms[49] and to let the processes of competition sort out the efficient and inefficient sizes. The current exchange control and capital funds control regimes usually do quite the opposite (White, 1974, chs. 2, 7). The establishment of an industrial extension service that would provide information on techniques and help solve problems for small businesses would probably be the best action that an LDC government could take (Hammond, 1974). But, like research institutes, effective extension services are easy to describe in principle and difficult to make work in practice.

The policy toward used machinery should also be relatively neutral. Neither a strongly pro- nor anti-used machinery policy seems warranted. Rather, reliance on the judgments of entrepreneurs--provided that the appropriate factor price and pro-competition policies are pursued --is warranted. Again, an information service to help on those judgments would be worthwhile.

The appropriate factor price and pro-competition policies, backed by some tougher bargaining by LDCs, would limit many of the possible abuses of MNCs.[50] Taxation policies on inappropriate products and an outward looking orientation that stressed labor intensive

exports would also help. And pressuring the MNCs to do more R&D in the LDCs is probably worthwhile.

Research institutes and information services, both national and international, are probably fruitful ways of encouraging more appropriate R&D by and for LDCs. But, again, it is easier to describe the good research institute than to operate it.

If the connection between good management and appropriate factor proportions is as crucial as much of the evidence suggests (with good management meaning that entrepreneurs can recognize and utilize the opportunities for appropriate factor proportions and also meaning that supervisory skills may be able to substitute for mechanization in the maintenance of quality standards), then appropriate management training institutes may be as important (or more so) as appropriate R&D institutes for discovering and applying efficient labor intensive methods.

Finally, a few words of caution: Appropriate technology is currently a fashionable topic of research and interest. There is, though, a serious risk. Appropriate technology is sometimes touted as a quick and easy way of raising LDC incomes to developed country levels. Five or ten years from now, after some (but not all) measures to encourage appropriate technology have been taken, many current enthusiasts will look around and notice that most of the people in LDCs are still very poor by developed country standards. They may then decide that appropriate technology was a fraud and will search for some other quick and easy solution. This would be unfortunate. Appropriate technology does not offer a simple solution to LDC problems; it cannot. There are no quick and easy solutions, short of a radical change in the relative supply-demand conditions for most

natural resources, comparable to that which has occurred in oil.[51] But appropriate technology can mean an improvement in the allocation of resources in LDCs, perhaps a slightly higher growth rate, a better distribution of capital resources across the economy and probably a slightly more equitable internal distribution of income, and more and better employment opportunities. The game should not be oversold, but it is definitely worth the candle.

NOTES

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1. This corresponds to the economist's notion of a set of production isoquants.
2. Some authors (e.g., Marsden [1971]) have also included suitability for small scale production, compatability with LDC cultures, and other desirable properties of technologies as part of "appropriate." See Westphal (1974) for a critique of these wider definitions.
3. It should be stressed that the model which follows is an ideal, and no country, developed or less developed, functions in the perfect manner described.
4. Only if technological change were to alter the underlying technology sufficiently so as to increase the demand for labor would employment be able to keep pace with output.
5. This would be due, in about equal thirds, to physical capital deepening, human capital deepening, and pure technological change.
6. This has come to be called the Harris-Todaro model. See Todaro (1969), Harris and Todaro (1970), and Todaro (1971). See also Berry (1974), Fields (1975), and Godfrey (1973).
7. This hypothesis is given powerful support by Turner and Jackson (1970) who find that the change of/rate of/. LDC urban unemplcyment is negatively related to LDC growth rates and positively related to the change in the ratio of urban incomes to economy-wide incomes.
8. E.g., through a wage subsidy.
9. Stewart (1974, p. 87) provides a calculation in a similar spirit.

10. The Pearson report (1970, p. 30) estimated average LDC saving at 15.0%/o and investment at 17.8%/o of GNP for 1960-1967.
11. In 1971 the ratio of fixed capital plus inventories to employees came to $20,000 (U.S. Bureau of the Census, 1973). This ignores working capital. It also underestimates replacement costs, since it is based on lower historical costs.
12. This assumes that the workers in the high productivity jobs will be able to capture some of that productivity in high wages.
13. See, for example, the ILO report cited in Kilby (1962) and see Adusei-Poku and Fiejka (1972, p. 306).
14. See Luders and Cabero (1972) for Chile, ILO (1972b, pp. 446-447) for Kenya, and Strassmann (1968, pp. 316-317) for Mexico. Occasionally, authors have been able to find cases in which LDC capital-labor ratios are <u>higher</u> than developed country figures. See Khan (1970a, 1970b), Bautista (1966), and Boon (1969, p. 213).
15. For more discussion of capacity utilization rates and their causes, see Winston (1971; 1974), Little, et al (1970, pp. 93-99), Kemal and Talat (1974), and Steel (1972).
16. For the original statement and estimation of the CES function, see Arrow, et al (1961).
17. This is the first order condition with respect to labor for profit maximization or cost minimization.
18. There is the problem of the possibility of selectivity of reporting: Only the favorable results may get published in journals.
19. There are also econometric problems of multicollinearity and simultaneous equations bias.
20. But Harris and Todaro (1969) and Tidrick (1970), for example, explicitly try to test for this and reject it as an explanation.

21. Some studies (e.g., Hewavitharna [1970]) do present alternatives but then simply look at comparisons of unit costs. If these costs incorporate inappropriate factor prices, the conclusions from the unit costs may not be trustworthy. But one can usually recreate the original factor proportions so as to examine the technologically efficient alternatives.
22. The abstracts in OECD (1974a; 1975) also appear to include more recent studies.
23. The costs of containers and pipes tend to increase with surface area, which rises more slowly as dimensions increase than the volume enclosed. See Silbertson (1972) and Scherer (1970, ch. 4).
24. This assumes that, despite the dilemma, it is still within the LDC's comparative advantage to produce the item rather than import it.
25. And, of course, the small producer who expects volume to grow has a yet crueler dilemma.
26. Diaz-Alejandro (1965) also tried to measure the same effect, but his study focuses only on output per worker and thus ignores the effects of varying capital intensities.
27. The literature on small firms has grown quite extensive. See Staley and Morse (1965), Dhar and Lydall (1961), Bhalla (1974), IBRD (1973), Paine (1971), Stepanek (1960), Fisher (1968), Shinohasa (1968), Oshima (1971), Watanabe (1974), and Vepa (1967; 1971).
28. Or one could argue that they sell different kinds of goods or different qualities, in which case the comparisons become largely irrelevant.

29. For some further theoretical discussions, see Sen (1962), Schwartz (1973), and Smith (1974).

30. But if the productivity of the used machine falls so low that its price is simply its scrap value, then it may or may not be a good buy for the LDC.

31. See White (1971, ch. 13) on this point for U.S. cars; see Alth (1968) for trucks.

32. Also see Cline (1972) and Tokman (1974, 1975).

33. The price ceilings, though, may have had the unintended effect of discouraging the <u>production</u> of white sugar.

34. Winston (1970) has also pointed out that exchange control and overvalued exchange rates make smuggling a highly profitable activity and that smuggling via over-invoicing on hard to value (by customs officials) capital goods provides yet another incentive for entrepreneurs to favor capital intensive processes.

35. See also Cordova (1972).

36. See, for example, Hicks and McNicholl (1971, p. 91) for the Philippines.

37. See Cooper et al (1975) for a description of a can manufacturer who simply failed to find out about the availability of a lower cost labor intensive method of production.

38. See Rethwisch (1974).

39. Todaro (1970), though, has argued that reliance on used machinery will still tie LDCs to a pattern of increasing capital-labor ratios over time, since this has been the pattern in the developed countries from which the used machinery comes.

40. See Marsden (1971) and Schumacher (1971a; 1971b; 1972; 1973).

41. Also, even patents may be a poor measure of the true output we wish, since there are clearly some patents which are more worthwhile than others.

42. See Kamien and Schwartz (1975) for a summary of this evidence.

43. For general discussions, see Sussex Group (1970); Stewart (1974); Eckaus (1966); Strassmann (1968, ch. 7); Herrera (1972); Nelson (1974); Solo (1966); Helleiner (1975a); and Bass (1973).

45. As Khan (1974) points out, since LDC industrial firms do not undertake much applied R&D, basic R&D by research institutes would be wasted.

46. Leff (1968, ch. 4) describes the way in which the Brazilian engineering industry was successful in obtaining foreign technology at reasonable costs; Streeten (1973) and Helleiner (1975b) also recognize that LDCs can be more effective bargainers.

47. This might have one unfortunate effect, if done in isolation. It would provide easier access to foreign capital intensive technology by local entrepreneurs and might bring out further the "engineering men" among them.

48. See Dhar and Lydall (1961) and Watanabe (1974).

49. See Di Tullio (1974).

50. For example, ending the tax concessions that make capital cheaper for MNCs would improve factor utilization and increase LDC taxes at the expense of profits. The questionarie data (if it is to be believed) indicates strongly that MNC location decisions are not affected by tax concessions (Hughes, 1969; Reuber, 1973, p. 128; Streeten, 1972b, p. 230; Schreiber, 1970, p. 75).

51. And even then, LDCs would still face serious political, social, cultural, and income distribution problems. It is not clear that Saudia Arabia is everyone's ideal of what an LDC that becomes rich should look like.

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