CHAPTER IV

# THE CHOICE OF INDUSTRIAL TECHNIQUES IN DEVELOPING COUNTRIES

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May 1985

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## Introduction

A major purpose of this paper is to consider whether, other conditions being met, the range of extant industrial techniques is sufficiently large and sufficiently dense to make optimal choices possible.[1/] This raises questions about the operational meaning of optimality. It also raises questions as to why the most desirable techniques might not be chosen, and of policies that might improve choice. In considering these it is important to recognize that the range of choice is continuously changing under the influence of technical progress, so that it has to be asked if particular techniques now available might not too quickly become obsolete or suffer from other disadvantages.

The main body of the paper is in three parts. The first considers the meaning of optimality and the characteristics of techniques; the second explores the availability of alternatives, their appraisal and the consequences of choice; and the third discusses some aspects of technical progress and the policy implications of the first two sections. Before turning to these substantial issues it is as well to acknowledge that, for some, reasons for dwelling on the choice of industrial techniques may not be self-evident. Moreover it is not difficult, as things now are in many countries, to create a presumption that returns to investment in peasant agriculture are higher than in other sectors.[2/] Even, however, if this were well-founded and acted upon, attention would still have to be paid to industrial development. Effective policies toward the peasants would lead to income growth which would increasingly translate into a demand for industrial goods - some at least of which could be expected to be produced domestically. Again a decision to give priority to peasant agriculture would - in virtually all developing countries - have to recognize the already established urban populations with their particular interests and patterns of demand.

Given that industrial development will continue, the methods of production used will affect the quantity of investible funds available in other sectors of the economy. This is particularly so if - as is widely believed - decisions have an urban bias which makes the allocation of resources outside the modern sector something of a residual matter - without necessarily ensuring that urban decisions are themselves efficient. Indeed many developing country plants are characterized by under-utilization of capacity, uncompetitively high unit costs, and consequently a record of loss-making. Why developing country industry should be thus inefficient is not a question to command a single answer. It may, however, be noted that part of the reason lies in the use of inappropriate techniques. More appropriate choice could consequently increase industrial efficiency and release investible funds for use in agriculture.

Close attention to the choice of technique could also help ease the employment problem. On the supply side this has its roots in unprecedentedly high rates of population and hence labour force growth. Taken in conjunction with poverty and the consequent low levels of savings, the rapid expansion in the number of workers can be translated into a (low) target cost per work place which would be consistent with substantial employment. For some the cost per job becomes a measure of the appropriateness of techniques. As will be seen this - on its own - is not satisfactory. Nor are more general prescriptions which make appropriate techniques either exclusively capital- or exclusively labour-intensive. To develop this argument would, however, quickly lead to the substantial discussion, so that it is now convenient to turn to this.

## I. Optimality and the Characteristics of Techniques

### (a) Some Theory and a Paradox

In conventional economic theory there is no great difficulty with the meaning and identification of an optimal technique. Consider what this theory has to say about the production, at a given level of output, of a well-specified product in a developing and a developed country location respectively. In the former it may be assumed that labour is relatively plentiful and capital relatively scarce, with the factor endowments being reversed in the developed country. The theory assumes that there are very many different ways in which the given good can be produced, and that factors are priced in keeping with their opportunity costs. It also assumes that the aim in both locations is to maximize profits. The optimal techniques will not, however, be the same in the two locations, since variations in capital-labour ratios are the standard response to variations in factor prices.

The choices of technique are illustrated in Figure 1. Reflecting relevant endowments, the factor price lines are

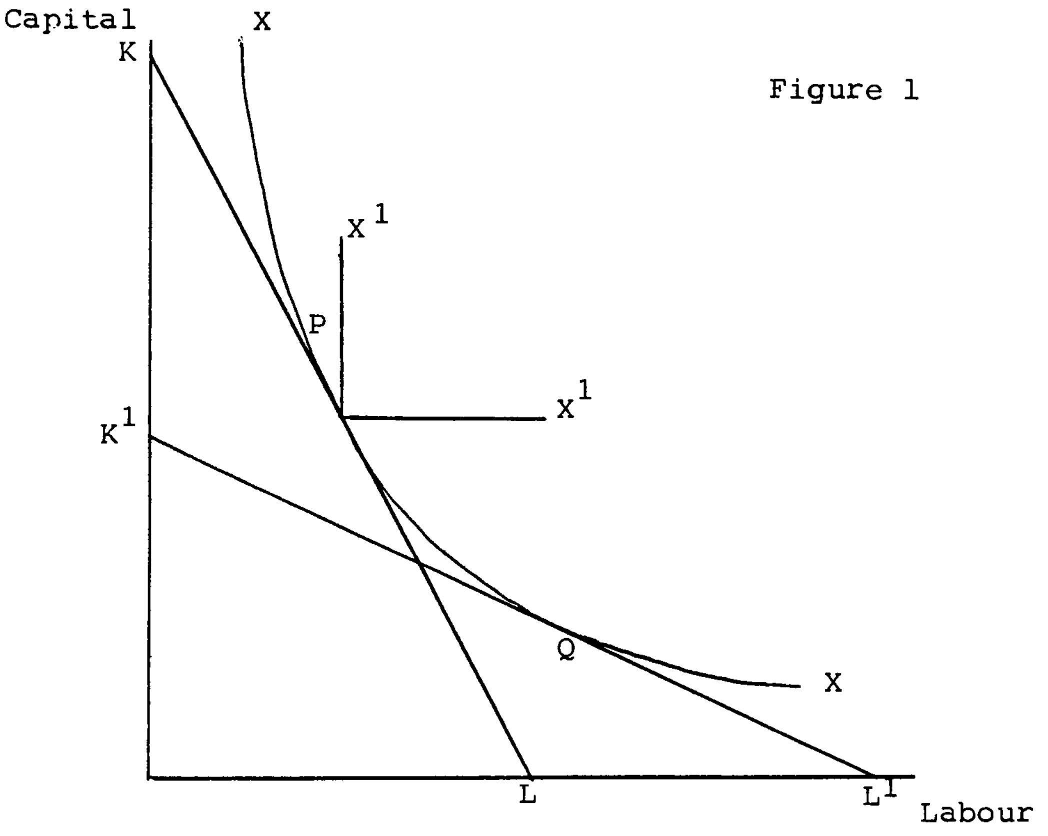


Figure 1: Optimal Techniques and Factor Endowments

KL (developed) and $K^1L^1$ (developing) respectively, so that, given the shape of the production isoquant XX, a factory located in a developed country would operate - as it were - at P and one in a developing country at Q. The points P and Q represent optimal techniques - i.e. least cost ones - defined by the condition that the marginal products of the two factors be proportionate to their prices.[3/]

If productive factors were internationally mobile the situation depicted in Figure 1 could not persist. Capital would move in one direction and labour in the other until relative factor prices were equalized and production characterized by a common capital-labour ratio.[4/] Mobility - particularly of labour - is, however, constrained. The presumption of different production techniques (capital-labour ratios) in different locations is, therefore, a reasonable one. 'Low'-wage countries should use labour-intensive and 'high'-wage countries capital-intensive methods of production. Yet the expected very wide spread of capital-labour ratios in any given industry is not generally to be observed as between developed and developing countries. Even in the latter the plant and machinery in use often seems more appropriate to factor proportions in rich than in poor countries. This is, of course, apparently paradoxical since it suggests that profits <u>and</u> employment are lower than they need be.

The failure of the theory to predict the behaviour of developing country decision takers could, of course, simply mean that there is something amiss with the theory. In this regard exception could be taken to the assumption of profit maximization, opportunity cost pricing and the plentiful availability of alternative techniques. If decision takers did not aim to minimize their production costs, other forces - including, for example, engineering pride, an aversion to 'troublesome' labour and national dignity - could come into play, particularly if markets were not competitive.[5/] The conditions that would be required for opportunity costs to be accurately registered in the market are not met in the second-best world of developing economies. In addition to other market imperfections, governments frequently act to cheapen capital in relation to its true opportunity cost and - in collusion with or under pressure from trade unions - to raise the price of labour. Consequently the price line $K^1L^1$ of Figure 1 has to be swivelled round in the direction of the developed country price line if it is to reflect observed prices. This done, a profit maximizing decision taker would choose a technique for a developing country that is much closer to that of the optimum choice in a developed country than it objectively should be. If there is little or no choice of techniques, the isoquant, XX, of Figure 1 is no longer appropriate. In the extreme it would be replaced by another isoquant, $X^1PX^1$, and the only choice in a developing country would be whether or not to use the one technique available.

These three explanations for the paradox would suggest different policy measures - increasing competition perhaps, getting the factor prices right and organizing a search for alternatives. Policies are discussed more fully below. In the meantime it is worth noting that all three constraints could be operating simultaneously. Screening by engineers could limit the effective choice to the capital-intensive reaches of the isoquant XX, with the selection from that limited range being made at distorted factor prices.

In the light of the foregoing, a little theory - even when it fails the supreme test of accurate prediction - seems to go a long way. Indeed it is convenient to explore one other feature of a theory that, in effect, assumes that only capital and labour vary across techniques. If this assumption were well-founded it would simplify methods of choosing among techniques - by justifying technical efficiency as a screening device.

(b) Technical Efficiency

Technical efficiency makes it possible to choose between techniques without reference to factor prices. If technique A uses less of both capital and labour than technique B, then - at any non-negative set of factor prices - it is clearly to be preferred to B. A should also be chosen if it uses less of one factor but no more of the other than B, and is said in these various circumstances to dominate A. Against this, if A uses more of one factor but less of the other than B it is no longer possible to choose between them by technical inspection. Economic calculation becomes necessary for choice. The techniques represented by the isoquant XX in Figure 1 comprise a technically efficient set among which choice is only possible on economic grounds. This does not, however, reduce the utility of the notion of technical efficiency since appeal to this would quickly rule out any techniques which would sit north and east of the isoquant.

Unfortunately the usefulness of the technical efficiency criteria is tightly tied to the assumption that techniques can be reduced to the relation between two homogeneous (or generally specified) factors. If different kinds of capital, different kinds of labour and varying quantities of raw materials have to be considered,the two-dimensional simplicity of Figure 1 disappears. The concept of technical efficiency can survive in a multi-dimensional world, but its operational effectiveness is much restricted;[6/] and in turning now to a more realistic consideration of what constitutes a technique than is to be found in Figure 1, it is necessary to stress that more changes with technique than the numbers of men and machines.

(c) The Meaning of an Appropriate Technique

For present purposes a technique may realistically be taken as the means and the methods to produce industrial goods. It consequently embraces a variety of factor inputs - including unskilled, semi-skilled, skilled, supervisory and managerial labour and capital tied up in machines, buildings, material stocks, work-in-progress and finished goods. Thus it is inadequate to describe techniques as being capital- and labour-intensive where capital refers only to machines and labour only to the unskilled. Techniques can also be skill-, management- or maintenance-intensive and to overlook this can result in seriously misleading results. A technique which employs much unskilled labour and relatively few machines can yet be more capital-intensive than a more mechanized alternative using fewer workers. The larger labour force could require higher expenditure on buildings, have a slower throughput and so a larger work-in-progress, and - because, for example, of more frequent breakages - need a larger stock of raw materials. Working capital, indeed, often represents one- to two-thirds of the total capital invested in a project. And, contrary to what is implicitly assumed in the theory discussed above, it does vary with the choice of technique.[7/]

In the light of these considerations it would be wrong to expect that any one industrial technique would be appropriate in all developing country locations. Even when scale of production and product characteristics are tightly specified, techniques appropriate to particular purposes in one country would be less so in another. Developing countries vary greatly in their availability of capital, various kinds of skills and general management competence. Consequently what is required is "a hierarchy of technologies appropriate to countries with a variety of scarcities and surpluses of different factors".8/

This variety notwithstanding, are there general standards that appropriate techniques drawn from this hierarchy should meet? Given the risks and uncertainties which surround industrial production this is not a question which should be approached dogmatically. Nevertheless it is useful to have an economically rigorous definition. Thus according to Sir Austin Robinson, an appropriate technique "is one which makes possible the production of a given good at a price not exceeding the current world price when:

(a) all factors of production are valued at prices that reflect their relative scarcities and opportunity costs and which will permit the full employment of all available supplies of all factors;

(b) the exchange rate is such that there is a balance of payments with this level of demand and activity, when allowance is made for a normal inflow or outflow of capital;

(c) the rate of interest or discount is consistent with a balance between savings and investment at this level of near full employment of all factors of production."

The crux of this definition is the use of opportunity cost, here stretched to include world prices and the exchange rate. Given the discount rate, a project life, and a full specification of alternative techniques, discounted cash flow analysis could capture the spirit of the definition by rank ordering economically-priced alternatives according to their net present values. That technique would be chosen that had the highest net present value - provided that this was positive when output was valued at the relevant world price. This way of applying the definition would - since NPV is a measure of economic surplus - correspond closely to the profit-maximizing assumption underlying Figure 1. The definition thus seems operational and consistent with the theory on which most economists are still brought up. In so far as the procedure just described could be used, the definition is operational and broadly provides the basis for the evaluation of techniques discussed below. Before turning to this, however, it is useful to register some caveats.

The definition differs from the partial equilibrium analysis underlying Figure 1 in that it has general equilibrium overtones. Granted an appropriate hierarchy of techniques, 'accurate' shadow pricing will deliver not merely the optimal technique in every line of production, but also full employment. This presumably is based on the usual neo-classical assumption that in any economy there will be some set of factor prices at which all markets including those for labour will clear.[9] Particularly in the light of the present levels of unemployment in the developed market economies this seems too heroic. Consequently the subsequent discussion in this paper does not include full employment as an objective. This is not, of course, to rule out a concern for fuller employment, so that the availability of employment-intensive techniques is still an important consideration. One characteristic of such techniques, so that more of them may be used, is that capital cost per job created should be less than, say, one-quarter of that associated with developed country techniques.[10/]

This choice of cut-off for the cost per work place is, of course, somewhat arbitrary. The underlying thought, however, is not. If massive un- and underemployment is to be avoided, developing countries have to find efficient techniques with capital-labour ratios much lower than those observed in the developed market economies. This may be illustrated by considering some aspects of the textile industry and some macro-economic features of the UK (a middle-range developed country) and Ethiopia (a particularly poor developing one). In present United Kingdom conditions, to set up an efficient factory of optimum size to produce grey cotton cloth would incur a capital cost of US $20 million and employ 240 persons, so that the capital-labour ratio would be US $83,333 per head. In Ethiopia the annual increment to the labour force may be put at 300,000. On the assumption of a savings rate of 10 per cent of the Ethiopian GDP, the absolute amount of investible funds available to Ethiopia may be put at US $9.3 million. This gives US $31 for each new entrant to the labour force. Against this, equipping new entrants to the standards of a British textile mill would require US $83,333 per head, so that if an attempt is made so to equip new workers the proportion of the 300,000 which could be employed in the modern sector would be miniscule. This proportion could rise, of course, if investible funds could be increased. In the present example, however, even if savings rose by a factor of 100 the point being made would remain.

This emphasis on the employment-intensive is important and possibly helps with another difficulty associated with full-blooded attempts to apply the above definition in empirical work - the need to use shadow prices. To estimate prices which accurately measured opportunity costs in all circumstances in which the appropriateness of techniques were to be judged is a tall order, particularly if investigation covers more than one country. Fortunately it may not be necessary to insist on shadow pricing. If there were techniques which seemed broadly efficient at market prices in developing countries,these would presumably be relatively sparing in their use of investible funds and relatively generous in their employment of unskilled labour. Given that shadow pricing would normally cheapen unskilled labour and make capital more expensive, appropriate 'market-price' techniques would be even more appropriate at true opportunity costs. Thus, the question is, do such techniques exist?

## II. The Hierarchy, Appraisal and the Consequences of Choice[11/]

### (a) The Production Process and the Range of Techniques

The first question that now arises is whether alternative techniques are available for the production of a closely-specified product (or product range) to some pre-determined level of output. Although some would deny that much choice exists,[12/] it is not difficult to create a contrary presumption.

Frequently the process of manufacture - of cotton cloth from raw cotton and of steel from iron ore, for example - begins with an agricultural or mineral raw material. At other times, however, the starting point is an intermediate product such as cotton and synthetic yarns and wool tops. Thus industrial processes can normally be divided into stages and the numbers of process techniques available will be a function of the number and 'independence' of stages and of the sub-techniques available at each stage. This view is supported by the fact that technical progress continuously improves and ultimately replaces existing machines - normally with faster and more automated alternatives. New machines, however, often cost more than older pieces of equipment for quite extended periods of time. They can also require more skilled labour and - like the air jet loom which weaves twice as quickly as the automatic loom, but wastes more cloth in the process - be more profligate in their use of material. For these reasons new machines do not on coming into production instantaneously displace existing machines. Instead, often for long periods, they increase the range of choice.

A production process then, in general consists of a number of separate, identifiable, sub-processes at each of which different sub-techniques may be used. In the brewing of beer, for example, the intake of raw materials, fermentation and beer filtration are separate sub-processes at each of which different methods of production may be employed. A sub-technique is a combination of inputs, some of which are fixed in equipment and last over all or a substantial part of the project, and some of which take the form of flows - like labour services and materials. A technique for any given industrial process comprises a combination of sub-processes (together with overhead provision which is for the present ignored). Suppose that two techniques of producing the same product are seen in use and that each of these comprises three separate and technically independent sub-processes - A, B and C. The two techniques and their sub-techniques are fully independent of each other, the number of techniques available is greater than those observed. In this example, the number of alternative techniques is eight - two of which are those observed and six are synthetic in that they are put together by mixing the sub-techniques that have been seen, but not in the combination in which they are now represented. For instance, $A_1+B_1+C_2$ is one synthetic technique, $A_2+B_2+C_1$ is another. More generally, if n is the number of techniques in use, and m is the number of sub-processes then - provided no two sub-techniques are the same - the total number of techniques which exist is $n^m$, of which $n^m$-n are synthetic.

To see the power of this method of identifying alternative techniques (and also to capture the realistic possibilities) consider the production of grey cotton cloth - a common good in developing countries. This is organized in eleven stages: opening and cleaning; carding; drawing; roving; spinning; cone winding; warping; slashing; drawing in; pirn winding;and weaving. It is convenient to number these stages, in the order given, from 1 to 11. It also necessary to allow for the fact that the number of stages is itself affected by the choice between ring and open-end spinning and between shuttle and shuttleless looms. Moreover, if open-end spinning is used then it is normally thought profitable to use manual doffing. Again, if open-end spinning is used then the type of draw frame required is different from that suitable for ring spinning,so that once the choice of spinning method is made there is no choice of drawing frame. Account may be taken of these factors by grouping the eleven stages in a way that reduces their number to seven. Thus, opening and cleaning, carding, warping, slashing and drawing in are all still considered separately. The remaining stages are taken in two groups: drawing up to and including cone winding; and pirning and weaving. In the first group there are fifteen alternatives currently available - twelve associated with ring and three with open-end spinning. In the latter there are eight options - five shuttle loom choices (allowing for the fact that pirn winding can be avoided if unifil equipment is used) and three alternative shuttleless looms.

The number of alternatives by stage may be tabulated as follows:

| Stage(s) | No of Alternatives |
|---|---|
| 1 | 6 |
| 2 | 1 |
| (3 + 4 + 5 + 6) | 15 |
| 7 | 1 |
| 8 | 1 |
| 9 | 3 |
| (10 + 11) | 8 |

so that the total number of techniques to be considered is 2,160.

In similar fashion it is possible to show that in the annual production of 300,000 pairs of men's shoes with leather upper and cemented-on synthetic soles the choice of alternative techniques runs in to the millions. In the production of lager beer 77 sub-processes may be identified. At six of these no effective choice of sub-technique exists, at eleven between four and six alternatives are to be found and in the remainder there are two-three alternatives. In the manufacture of solid clay-fired common brick four stages of production may be distinguished. At the first of these, winning the clay, there are at least five alternatives which could be considered; at the second, preparation of the clay and brick forming, at least a dozen options present themselves; at the third stage, the drying and handling of the bricks, there are six options; and at the final stage of firing and the removal of the bricks from the kiln, there are five choices. Again, in the process of leather manufacture there are fifteen distinct stages at most of which there are two or more choices of sub-process techniques.

This apparently plentiful supply of alternative techniques might be thought to be a characteristic of the particular industrial processes mentioned. In the batch manufacture of bolts and nuts, however, the range of choice is still impressive. Even when attention is confined to three different technology types - machining (on lathes), cold forming and hot forging - choices arise from the fact that the machines being used within each technique differ in respect of speed, automation and flexibility. Moreover mixes of two or more technology types within one factory are possible - and indeed in view of the nature of the batch industry and the differing requirements for different size bolts are likely to be advantageous. Again, in common with the processes already mentioned, machines with specific characteristics are frequently available from a range of manufacturers in developed and, often enough, developing countries.

(b) Least-Cost and Other Techniques

It is clear that for the processes mentioned (and in fact others) the scope for choice is very considerable. Moreover, the range of techniques is normally correspondingly wide - stretching, for example, in textile weaving from the modern, high-speed projectile loom to the 3,000 year-old, very simple, pit loom.[13/] Lack of choice is consequently not apparently a constraint on the search for an optimum technique, if this is construed as least-cost and, in some cases, capable of meeting the world price. Indeed for purposes of evaluation the choice sometimes seems embarrassingly great. Fortunately (least-cost) choices can be made for each sub-process, so that the need to undertake evaluations of many alternative, complete, techniques can be avoided. This is not to say that evaluation is thereby easy. Every investment decision should be location specific and so incorporate (realistic) assumptions about, for example, machine and labour productivity.[14] Establishing such assumptions, particularly for labour, is difficult. It is not, however, impossible; and discounted cash flow analysis applied to sub-processes can be used first to identify the least-cost technique in given circumstances and second to permit comparison between this and other selected techniques.

The possibilities in this regard may be illustrated by reference once more to textiles. One study[15] which took account of observed machine and labour efficiency concentrated on choices from the full range for the UK and for three representative LDC wage areas. The 'high' wage regime was taken as broadly that of Latin America and Hong Kong; the 'medium' regime that of countries at about the Ghanaian level of development; and the 'low' regime that of the least developed. The product in question was grey cotton cloth,[16] and the level of output some 28 million yards per annum, so that technical economies of scale were fully realized. The main results of the study are summarized in Table 1 which covers three techniques: the least-cost, the most capital-intensive, and the most labour-intensive. From the table it may be seen that the manufacture of cloth appeared profitable in all three developing areas, but most so in the low-wage regime.[17]

For each wage area, Table 1 compares the least-cost with the most capital- and most labour-intensive techniques. It

Table 1

NET PRESENT VALUES, CAPITAL AND OPERATING PRESENT VALUE COSTS AND EMPLOYMENT ASSOCIATED WITH SELECTED TECHNIQUES CAPABLE OF PRODUCING 28 MILLION YARDS OF COTTON CLOTH PER ANNUM IN FOUR WAGE AREAS AT A 10 PER CENT DISCOUNT RATE AND 20-YEAR PROJECT LIFE

| Characteristics \ Technologies | Least-cost | Most capital-intensive | Most labour-intensive |
|---|---|---|---|
| 1. Discount rate | 10 per cent | 10 per cent | 10 per cent |
| (a) United Kingdom | | | |
| 2. Net present value (US $000) | - | - | - 23,708 |
| 3. Capital costs (US $000) | 19,289 | 19,289 | 11,380 |
| 4. Operating costs (US $000) | 85,248 | 85,248 | 116,865 |
| 5. Employment (No.) | | | |
| Total | 240 | 240 | 754 |
| skilled | 66 | 66 | 87 |
| unskilled | 174 | 174 | 667 |
| (b) High-wage area | | | |
| 2. Net present value (US $000) | 35 | -281 | - 7,389 |
| 3. Capital costs (US $000) | 22,113 | 22,113 | 12,920 |
| 4. Operating costs (US $000) | 82,389 | 82,705 | 99,006 |
| 5. Employment (No.) | | | |
| Total | 392 | 368 | 860 |
| skilled | 97 | 100 | 106 |
| unskilled | 295 | 268 | 754 |
| (c) Medium-wage area | | | |
| 2. Net present value (US $000) | 3,127 | - 1,007 | 407 |
| 3. Capital costs (US $000) | 18,496 | 23,695 | 13,543 |
| 4. Operating costs (US $000) | 83,008 | 80,735 | 90,587 |
| 5. Employment (No.) | | | |
| Total | 872 | 674 | 1,769 |
| skilled | 196 | 223 | 247 |
| unskilled | 676 | 451 | 1,522 |
| (d) Low-wage area | | | |
| 2. Net present value (US $000) | 5,470 | - 113 | - 2,036 |
| 3. Capital costs (US $000) | 13,392 | 24,072 | 13,173 |
| 4. Operating costs (US $000) | 85,675 | 80,567 | 88,728 |
| 5. Employment (No.) | | | |
| Total | 3,004 | 1,486 | 3,499 |
| skilled | 428 | 401 | 428 |
| unskilled | 2,576 | 1,085 | 3,071 |

thus establishes that the least-cost technique in the UK is also the most capital-intensive; and in the high-wage area the least-cost and the most capital-intensive are very close. In the medium-wage area the least-cost technique is intermediate between the most capital- and the most labour-intensive; and in the low-wage areas, the least-cost is quite close to the most labour-intensive. It is worth noting that each of the techniques in the least developed countries has an absolutely greater skill requirement than in the UK. It may also be calculated from the table that the proportion of the most labour-intensive manning requirements met by the least-cost technique would be 45, 49 and 85 per cent in the high, medium and low wage areas respectively. Thus, overall, the results are pleasing. At a level of production likely to help minimize unit costs, the optimal technique more nearly produces 'maximum' employment the poorer the country.

The alternative techniques considered are 'synthetic' in the sense that, although they comprise sub-techniques which are generally observable in use, they are not necessarily to be found to be in working practice as complete processes. They are nevertheless robust and feasible, so that, if widely repeated for other industries, the foregoing results would be encouraging, without necessarily being entirely satisfactory in their employment implications. Generally speaking unit costs are likely to be lowest when economies of scale are fully exploited, and the higher the output the more capital-intensive techniques are likely to be preferable to labour-intensive ones. Thus in looking for replication of the textile results it is useful to confine attention to relatively large-scale activities. In this regard attention may first be given to iron founding where annual outputs of 1,000, 4,000 and 12,000 tonnes of 'good' castings provide the basis for the industry's own classification of small, medium and large foundries.18/ For an annual output of 12,000 tonnes, the net present values of alternative techniques - at prices and costs broadly of the Indian sub-continent and over a 20 year project life - at various discount rates, are as shown in Table 2.

Table 2

NET PRESENT VALUES AND EMPLOYMENT OF ALTERNATIVE FOUNDING TECHNIQUES

| Technique | No. Employed | Net Present Values at 5 per cent | at 10 per cent (in £ 000's) | at 30 per cent |
|---|---|---|---|---|
| Hand Moulding | 281 | 30,180 | 18,222 | 8,696 |
| Mechanized Moulding | 206 | 30,508 | 18,354 | 8,688 |
| Conventional Automated Moulding | 198 | 30,422 | 18,266 | 8,602 |
| Flaskless Automated Moulding | 196 | 30,282 | 18,136 | 8,481 |

From the table it may be seen that at all but an unreasonably high discount rate the hand moulding technique - which provides most employment - does not quite match mechanized moulding in profitability, although it comes close to it. At the small- and medium-scale, however, hand moulding would be generally chosen.

Another process which has been studied in relation to the choice of technique is that of mill-white sugar manufacture. Here argument has been made that, when high levels of output - say 50,000 tonnes of sugar per annum - are considered, the most capital-intensive variants of modern vacuum-pan techniques should be used. Thus one investigation[19/] which focused on Ghana found that even when shadow prices were used the results of Table 3 were obtained.

Table 3: EMPLOYMENT, CAPITAL-LABOUR RATIOS AND NPVs OF ALTERNATIVE SUGAR TECHNIQUES

| Technique | No. of Employees | K/L (In Cedis) | Net Present Value (¢ Million at 10 per cent) |
|---|---|---|---|
| 1 | 1,030 | 7,874 | 32.8 |
| 2 | 1,054 | 7,608 | 32.6 |
| 3 | 1,409 | 4,923 | 32.6 |
| 4 | 1,796 | 4,425 | 31.3 |
| 5 | 1,680 | 3,682 | 24.6 |
| 6 | 2,474 | 3,099 | 25.6 |
| 7 | 2,589 | 2,953 | 25.3 |
| 8 | 2,614 | 2,891 | 25.1 |
| 9 | 2,118 | 2,609 | 14.5 |

The iron founding and sugar results - although drawn from studies which confirm that there are choices of technique - are, on the face of it, less encouraging than those for textiles. On closer inspection, however, one need not be too despondent. It is apparent from the data presented on iron founding that the range of profitability across the techniques considered is narrow and relatively much less than that for employment. The same is evidently true of sugar, where technique 4 would provide some 74 per cent more employment than technique 1, but earn more than 95 per cent of its profit.[20/] These findings are of some generality and readily understandable when it is recognized that capital and labour combined account normally for considerably less than

50 per cent of the present value of total costs. It is thus not surprising that profitability should vary less across techniques than investible funds and employment, so that the trade-off between profitability and employment could often be acceptably small. Encouragement is consequently restored to the results.

Before considering some policy questions which are suggested by results of the kind described, it is useful to examine one or two aspects of the evidence more closely. It is widely believed that techniques used in developing country industry are often delivered on a turn-key basis. This it is assumed, means that such techniques are capital-intensive. Given this it is worth explicitly remarking on possible consequences of choices of this kind. This may be done by reverting to the textile results given in Table 1. From these it is clear that if, for example, the most capital- intensive technique were installed in a low-wage area, the profit (over the project life) of US $5.5 million which would be generated by the least-cost technique would become a loss of US $113 thousand. Moreover, the investment costs for a factory would be almost 80 per cent higher and employment some 50 per cent lower than if the least-cost technique were used. These figures suggest that critical choices are worth making.

In the light of what was said earlier about costs per work-place, it is of interest to consider investible funds per worker associated with the least-cost and capital-intensive technique.

From Table 1 these may be put, for the low-wage area, at US $4,458 and US $16,200 respectively. The ratio of these figures is 27.5 per cent, so that the suggested target of less than 25 per cent is within reach. A capital-labour ratio of US $4,458 is still, however, more generous than many poor countries could afford to pay in equipping their labour forces. The evidence deployed so far largely relates to modern technology. Given a capital constraint, however, it is pertinent to ask whether there is any efficient scope for more traditional, and generally much less capital-intensive, techniques.

(c) Modern versus Traditional Techniques

In this regard attention may once again be turned to textiles and sugar. In textiles, hand-spinning and hand-weaving organized as a cottage industry are no match for modern methods. Improved versions of these would do better if organized on a factory basis - probably, to exploit technical economies of scale, with an annual capacity of 200,000 yards of cloth. They would do even better still if advantage were taken of improvements made to traditional techniques by the Indian Appropriate Technology Association. These would achieve their technical optimum at an output of 1.2 million yards per annum. Some comparative data, for Indian conditions, are given in Table 4. The calculations underlying the table assumed a discount rate of 10 per cent and a project life of 20 years. They were made net of taxes and subsidies but were otherwise based on market prices. Techniques A to E in the table are modern, and the first five rows quantify the economies of scale.

Table 4

PRESENT VALUE COSTS AND EMPLOYMENT IN THE PRODUCTION OF 28 MILLION YARDS OF CLOTH PER ANNUM WITH SELECTED TECHNOLOGIES AND FACTORY SCALES

| Mill | Present Value costs ($ 000) | Employment (No.) | Present value cost in excess of minimum ($000) | Increase in employment over least-cost (No.) | Cost per additional job compared to least-cost ($) |
|---|---|---|---|---|---|
| A (1)[a] | 100,240 | 3,024 | - | - | - |
| B (1)[a] | 102,480 | 2,094 | 2,240 | 70 | 32,000 |
| C (4)[a] | 105,560 | 3,198 | 5,320 | 174 | 30,574 |
| D (20)[a] | 136,640 | 4,410 | 36,400 | 1,386 | 26,263 |
| E (40)[a] | 169,960 | 5,818 | 69,720 | 2,794 | 24,953 |
| F (140) | 319,480 | 47,488 | 219,240 | 44,464 | 4,931 |
| G (24)[b] | 140,560 | 11,337 | 40,320 | 8,333 | 4,838 |

a With ordinary looms - i.e. power driven but non-automated shuttle changing.

b More exactly, 23.33. In making the PVC and employment calculations the relevant figures for one-third of a factory have been taken on a pro-rata basis.

Key: A = 28 million yard factory; B = 14 million yard factory; C = 7 million yard factory; D = 1.4 million yard factory; E = 700 thousand yard factory; F = Hand-operated factory; and G = 'intermediate' factory. The numbers in brackets refer to factories required to produce 28 million yards. Hand-operated and intermediate factories are described in paragraph 34.

From Table 4 it is clear that neither hand-operated nor intermediate factories would be optimal choices. Both could, however, provide much more employment per unit of output than any of the modern factories and do so much more cheaply than any sub-optimal modern method. Yet the cost per additional job - almost US $5,000 - seems unduly high for a country with a per capita income of about US $100, so that these options should be ruled out. The use of market prices in the comparative evaluations could cause unease. The larger mills considered are likely to be located in or near urban areas, the smaller factories in rural ones, so that - given imperfections - the 'market' wages could differ in the two sectors. There are also the familiar arguments which underpin shadow pricing and would call for a revaluation of labour and other inputs in both sectors. In convenient, if somewhat pragmatic, recognition of these arguments Table 5 compares the modern technically optimal factory with the hand operated and 'intermediate' operations: (a) when 'market' wages are paid by the large factory and 50 per cent of those in the smaller sector; (b) where wages are reduced by half in all factories.

Table 5

COSTS AND EMPLOYMENT IN MODERN, HAND-OPERATED AND 'INTERMEDIATE' FACTORIES IN PRODUCTION OF 28 MILLION YARDS OF CLOTH PER ANNUM AT DIFFERENT WAGE RATES

| Factory type / Cost and employment | 'Modern' factory | | Hand operated factory | 'Intermediate' factory |
|---|---|---|---|---|
| | full wages | half wages | half wages | half wages |
| PVC of cloth per yard ($) | 3.58 | 3.12 | 7.25 | 3.83 |
| Employment (no.) | 3,024 | 3,024 | 47,488 | 11,357 |

Changing the wage rates in this way clearly helps the small-scale activities. The unit cost of the hand-operations is still unacceptably high. The position of the 'intermediate' is, however, much more marginal than before. If differential wage rates were in order, then the use of 'intermediate' methods would increase employment for the production of 28 million yards of cloth by 8,333 at a cost per job of US $840. If wages in both the modern and 'intermediate' factories were the same but shadow priced, then the cost of creating an additional workplace would be US $2,386. Perhaps the safest conclusion to draw from these figures is that it could be rewarding to undertake more research and development on the traditional processes.

An important limitation on the work on sugar discussed above is that it was confined to the factory. Sugar production, however, involves an extensive agricultural operation which itself produces an output (cane) for which no feasible alternative market other than processing currently exists (except at very low levels of output, when the cane is chewed directly by humans or fed to cattle). Moreover, once cut, sugar cane deteriorates at such a rapid rate that it has to be processed in the immediate vicinity of the fields. Interaction between field and factory is therefore of relevance to any investigation of the manufacturing process. A later study took this into account and, in selected African conditions, compared the efficiency of the modern vacuum-pan technique with that of the more traditional open-pan technique.[21] Two seasons were considered and both were evaluated for rainfed and irrigated agriculture. Four levels of output were studied: 100 and 200 tonnes of cane per hour (for the vacuum-pan factories) and 100 and 150 tonnes of cane per day (for the open-pan operations). In the long season, rainfed situation the 150 tonnes of cane per day factory would be the first choice at 5 and 10 per cent real discount rates and market prices. The larger of the two open-pan factories would however be preferable to the smaller of the vacuum-pan factories and would be sufficiently close to the largest factory in profitability to place the two in a small trade-off situation with respect to employment. Shadow pricing of labour, foreign exchange and the selling price of sugar gave the results shown in Table 6. From this it is evident that the larger of the two open-pan factories should now be chosen.

Table 6

ECONOMIC NET PRESENT VALUES FOR PLANTATION MODELS ON ALTERNATIVE ASSUMPTIONS (US$ PER TONNE OF SUGAR PER ANNUM)

| | Discount rate (%) | |
|---|---|---|
| | 5 | 10 |
| Long-season, rainfed | | |
| 200 tch | 1579 | 576 |
| 100 tch | 1089 | 258 |
| 150 tcd | 1870 | 904 |
| 100 tcd | 1685 | 777 |

The sugar evidence is not conclusive. It does, however, rule out strong argument that there is little scope for open-pan techniques. On the contrary the evidence suggests that, in certain really identifiable conditions, some African governments at least should be encouraged to meet a demand for, say, 50-100,000 tonnes of sugar per annum by the establishment of a number of small, open-pan factories rather than by the erection of a single, large-scale, vacuum-pan plant. In this regard it should be noted that to obtain the same output - 110,000 tonnes of sugar per annum in a long season - as the 200 tonnes of cane per hour factory,would require 47 small-scale factories each with a capacity of crushing 150 tonnes of cane per day. The capital costs of these factories would in aggregate be considerably less than that of the single large factory. Moreover,the small-scale factories would provide employment for about 28,000 persons -

divided equally between factory and agriculture. This compares with a factory employment of 633 and a field labour force of 6,200 for the vacuum-pan process.

(d) Actual Choices

What emerges from the discussion is that there are choices available in a wide range of industrial processes from extant techniques. It has also been seen that, given the cost of not doing so, it is important that correct choices be made. The pertinent costs lower the profitability, raise necessary investment costs per factory, and lower employment per factory. For the economy as a whole the economic surpluses are less than they could be and the level of employment lower than would be possible. All in all, therefore, it is worth asking: are 'proper' choices made? Although this question has been around for a long time there is still surprisingly little in the way of systematic answer.[22/] There is, however, a strong presumption that developing country choices are more capital-intensive and sophisticated than they should be. This is supported by casual impressions and by some more rigorous studies. In this regard reference may be made to an investigation covering leather and sugar manufacturing in developing countries. For each of the industries a sample of between 20 and 30 factories was constructed with each sample covering 10 developing countries. The samples covered various levels of output, forms of ownership, and, evidently, locations.[23/] All of the factories in the sample were visited. Information was obtained which enabled realistic calculations to be made of the profitability of observed techniques and which supported calculations of the likely profitability of alternative techniques. Results from this investigation covering 12 leather and 12 sugar factories are given in Table 7.

It should be emphasized that the alternative techniques covered by the table were derived by making changes at a very limited number of sub-processes in each of the two industries, so that the results of the table do not capture the full benefits that would have accrued from a different choice of technique. Nevertheless it can be seen from the table that the use of a different technique would have generally increased the profitability of operations. It is also evident that fuller capacity utilization of the techniques than observed would have similarly increased profitability. In some cases the gains from more effective utilization of existing techniques exceed those that could be had from improved choice. The largest gains, however, obviously come from using better techniques to capacity.

## III. Policies and Technical Progress

### (a) Reasons for Inappropriate Choice

In considering policies to improve choices of technique it would obviously be helpful to know why 'wrong' choices were made.[24/] This is not likely to be a simple matter. It can, however, safely be said that one explanation for inappropriate choice - a lack of alternatives - does not hold up.

A second explanation, foreshadowed in the earlier discussion of Figure 1, is that factor prices are 'distorted'. It would be difficult for most economists to gainsay the proposition that getting the factor prices right is important.

Table 7

ECONOMIC EVALUATION OF ALTERNATIVE TECHNIQUES

Leather Manufacturing

| Factory No. | Discount Rate | Actual Tech. at observed capacity (Actual NPV) | Actual Tech. at Fuller capacity utilization | Difference from Actual NPV | Alternative Tech. at observed capacity utilization | Difference from Actual NPV | Alternative Tech. at fuller capacity utilization | Difference from Actual NPV | Fixed Investment | | Employment (No.) | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | | | | | | | | | Actual Tech. | Difference with best alternative tech. | Actual Tech. | Difference with best alternative tech. |
| 1. | 10% | 16 | 2,059 | 2,043 | 42 | 26 | 2,110 | 2,094 | 1,553 | - 71 | 228 | 20 |
| | 20% | -945 | -29 | 916 | -902 | 43 | 30 | 975 | | | | |
| 2. | 10% | 10 | 1,753 | 1,743 | 219 | 209 | 1,951 | 1,941 | 2,095 | -215 | 256 | 23 |
| | 20% | -1,152 | -441 | 711 | -957 | 195 | -251 | 901 | | | | |
| 3. | 10% | 2,493 | 3,822 | 1,329 | 2,575 | 82 | 3,911 | 1,418 | 1,968 | -120 | 232 | 18 |
| | 20% | 50 | 580 | 530 | 142 | 92 | 673 | 623 | | | | |
| 4. | 10% | 1,227 | 2,171 | 944 | 1,427 | 200 | 2,379 | 1,152 | 1,706 | -159 | 195 | 8 |
| | 20% | -370 | 4 | 374 | -205 | 165 | 174 | 544 | | | | |
| 5. | 10% | 815 | 2,020 | 1,205 | 890 | 75 | 2,103 | 1,288 | 1,217 | -88 | 151 | 9 |
| | 20% | -605 | -66 | 539 | -533 | 72 | 11 | 616 | | | | |
| 6. | 10% | 1,289 | 1,289 | 0 | 1,315 | 26 | 1,315 | 26 | 522 | -16 | 104 | 2 |
| | 20% | 335 | 335 | 0 | 355 | 20 | 355 | 20 | | | | |
| 7. | 10% | -1.5 | 114 | 115.5 | 110 | 111.5 | 358 | 359.5 | 717 | -240 | 103 | 8 |
| | 20% | -368 | -321 | 47 | -193 | 175 | -95 | 273 | | | | |
| 8. | 10% | 4,880 | 7,123 | 2,243 | 4,918 | 38 | 7,160 | 2,280 | 943 | -18 | 148 | 4 |
| | 20% | 1,665 | 2,625 | 960 | 1,696 | 31 | 2,646 | 981 | | | | |
| 9. | 10% | 31,320 | 31,320 | 0 | 31,339 | 19 | 31,320 | 0 | 3,294 | -12 | 255 | 3 |
| | 20% | 12,163 | 12,163 | 0 | 12,176 | 13 | 12,163 | 0 | | | | |

Table 7 (cont/d.)

Leather Manufacturing

| Factory No. | Discount Rate | Actual Tech. at observed capacity (Actual NPV) | Actual Tech. at fuller capacity utilization | Difference From Actual NPV | Alternative Tech. at observed capacity utilization | Difference from Actual NPV | Alternative Tech. at fuller capacity utilization | Difference From Actual | Fixed Investment: Actual Tech. | Fixed Investment: Difference with best Alternative Tech. | Employment (No.): Actual Tech. | Employment (No.): Difference with best Alternative Tech. |
|---|---|---|---|---|---|---|---|---|---|---|---|---|
| 10. | 10% | 2,501 | 2,501 | 0 | 2,542 | 41 | 2,501 | 0 | 465 | -30 | 104 | 5 |
| | 20% | 143 | 143 | 0 | 170 | 27 | 143 | 0 | | | | |
| 11. | 10% | 5,180 | 5,180 | 0 | 5,223 | 43 | 5,180 | 0 | 1,033 | -27 | 164 | 4 |
| | 20% | 870 | 870 | 0 | 911 | 41 | 870 | 0 | | | | |
| 12. | 10% | 1,410 | 1,782 | 372 | 1,469 | 59 | 1,841 | 431 | 1,107 | -50 | 129 | 8 |
| | 20% | 33 | 180 | 147 | 81 | 48 | 228 | 195 | | | | |

Sugar Industry (there is no evaluation of alternative technology at fuller capacity utilization)

| Factory No. | Discount Rate | Actual Tech. at observed capacity (Actual NPV) | Actual Tech. at fuller capacity utilization | Difference From Actual NPV | Alternative Tech. at observed capacity utilization | Difference from Actual NPV | Alternative Tech. at fuller capacity utilization | Difference From Actual | Fixed Investment: Actual Tech. | Fixed Investment: Difference with best Alternative Tech. | Employment (No.): Actual Tech. | Employment (No.): Difference with best Alternative Tech. |
|---|---|---|---|---|---|---|---|---|---|---|---|---|
| 1. | 10% | -10,924 | -7,993 | 2,931 | - | - | | | 9,750 | - | 2,270 | - |
| | 20% | -10,050 | -8,544 | -1,506 | - | - | | | | | | |
| 2. | 10% | -14,252 | -11,530 | 2,822 | -11,549 | 2,803 | | | 23,229 | -247 | 2,144 | 177 |
| | 20% | -19,433 | -18,121 | 1,312 | -18,025 | 1,408 | | | | | | |
| 3. | 10% | -2,456 | - | - | -1,553 | 903 | | | 22,588 | 405/ -805 | 3,591 | -/ 498 |
| | 20% | -14,241 | - | - | -13,898 | 343 | | | | | | |
| 4. | 10% | -23,589 | -20,682 | 2,907 | -22,705 | 884 | | | 32,207 | 72 | 2,769 | - |
| | 20% | -28,203 | -26,851 | 1,352 | -27,826 | 377 | | | | | | |

Table 7 (cont/d.)

Sugar Industry

| Factory No. | Discount Rate | Actual Tech. at observed capacity utilisation (Actual NPV) | Actual Tech. at fuller capacity utilization | Difference From Actual NPV | Alternative Tech. at observed capacity utilization | Difference From Actual NPV | Fixed Investment | | Employment (No.) | |
|---|---|---|---|---|---|---|---|---|---|---|
| | | | | | | | Actual Tech. | Difference with best alternative tech. | Actual Tech. | Difference with best alternative tech. |
| 5. | 10% | -1,747 | -1,460 | 287 | -1,356 | 391 | 3,190 | 63 | 829 | - |
| | 20% | -2,671 | -2,537 | 134 | -2,518 | 153 | | | | |
| 6. | 10% | -12,073 | -10,770 | 1,303 | -10,151 | 1,922 | 16,820 | -1,731 | 3,160 | - |
| | 20% | -16,936 | -16,330 | 606 | -15,221 | 1,715 | | | | |
| 7. | 10% | -3,948 | -3,328 | 620 | -2,162 | 1,786 | 6,295 | -314 | 962 | - |
| | 20% | -5,667 | -5,379 | 288 | -4,703 | 964 | | | | |
| 8. | 10% | -6,348 | -5,057 | 1,291 | - | - | 3,693 | - | 1,063 | - |
| | 20% | -5,081 | -4,460 | 601 | - | - | | | | |
| 9. | 10% | -4,408 | -3,658 | 750 | -3,492 | 916 | 6,065 | -158 | 1,478 | - |
| | 20% | -5,616 | -5,267 | 349 | -5,115 | 501 | | | | |
| 10. | 10% | -3,906 | -3,658 | 248 | -3,383 | 523 | 5,002 | 45 | 1,294 | - |
| | 20% | -4,603 | -4,488 | 115 | -4,381 | 222 | | | | |
| 11. | 10% | -18,526 | -7,731 | 10,795 | - | - | 14,382 | - | n.a. | - |
| | 20% | -16,042 | -11,091 | 5,023 | - | - | | | | |
| 12. | 10% | -5,238 | -4,678 | 560 | -4,394 | 844 | 16,048 | 73 | 1,581 | - |
| | 20% | -10,363 | -10,100 | 263 | -10,005 | 358 | | | | |

This is not the same thing, however, as saying that doing so would result in optimal choices of industrial techniques in developing countries. For a start it is not clear from the detail which underlies much of the evidence discussed in the last section that, say, UK-Ethiopian factor price ratios are sufficiently out of kilter as to provide an explanation for Ethiopian choice of, for example, more capital-intensive textile techniques than would be found in the UK. More generally, the view that getting the factor prices right is both a necessary and sufficient condition for optimal choices clearly relies heavily on the assumption of profit maximization. Particularly, however, in the imperfect economies of developing countries the scope for less than dedicated marginal pursuit of this objective is considerable. One way in which this is manifest is in the influence of the engineer. The engineer's instinct is to use, as a matter of professional pride and training, best-practice techniques. This instinct coincides increasingly with the aversion of many managers to a large and, in their eyes, troublesome labour force. Management has its own set of shadow prices and implicit collusion could have these survive a strengthening of competition. Thus, although the search for appropriate techniques may be presumed to be the more intensive the greater the degree of competition in the economy, it looks as if there are elements in the situation which could go beyond factor prices.

What, then, is to be done - beyond introducing more competition and encouraging sensible factor pricing? In a sense the greatest need is that of increasing the knowledge available to individual developing countries of the alternatives that are there. The costs of conducting the investigations that have provided most of the empirical material for this paper are relatively modest. It should, consequently, be possible for developing countries, acting severally or jointly, to establish groups which could assess the availability of techniques on a continuing basis. Such groups would have to acquire a competence in the financial and economic evaluation of industrial techniques; and the best way of doing this would be to undertake industry studies.

Even if the relevant knowledge were widely available and appreciated it would still have to be translated into policy influence. This is a more difficult matter and not one that can be legislated for in a general way. It may, however, be noted that in most developing economies the role of the public sector in industrial development is considerable.

(b) Technical Progress and the Choice of Technique

Like the literature of which it forms part, this paper has not been as sharply focused as would be desirable. Nevertheless it is hoped that its drift is clear. It registers and supports a view that better choices of industrial technique are possible than many that have been made in developing countries. Such improved choices would possibly move the 'average' choice much nearer the labour-intensive end of the spectrum than it now is. Insofar as this is so, there could be a fear that static choices of technique could lock a country into a pattern of technological development that would be unhelpful in the light of technical progress. It is not, however, clear that this would be so. Careful choice of labour-intensive techniques has until the present been an important element in the dynamic strategy of countries at one level of development wishing to move to a higher one.

Thus Taiwan in the early 1950s adopted an import substitution policy which was quite similar to that adopted by many other developing countries. While this policy was being followed,the population grew by about 3.6 per cent per annum. Manufacturing increased rapidly, imports of consumer goods fell absolutely and relatively, those of capital goods increased markedly, and exports increased modestly. After a decade Taiwan had a large deficit in international trade and had experienced but modest growth in employment, so that overt unemployment was estimated at 6 per cent and 'underemployment' at half of the labour force. The domestic market remained small, the natural resource base was poor, agriculture had come close to the limit of labour absorption and offered agro-industrial expansion, and the balance of payments constraint restricted the import of capital goods. In these conditions an extension of the existing import substitution policy to cover those consumer goods still being imported and intermediate and capital goods would have been difficult. Instead the policy adopted - in the light of surplus labour and low initial wage rates - focused on the export of labour-intensive manufactured goods with low capital-output ratios. In the event exports, total output and employment increased dramatically and by the mid-1970s full employment had been attained. A somewhat similar story could be told of

19th-20th century Japan and of the Republic of Korea since 1960.[25]

These telling tales do not dispose entirely of doubts induced by consideration of dynamic links between present choices of technique and subsequent technical progress. The view has been taken that contemporary factor prices determine the choice of technique which in turn - by a kind of learning by doing and using - greatly influences the pattern of research and development.[26] Considerably oversimplifying a complex argument, if static choices of technique were in developing countries to result in choices which were more labour- than capital-intensive then, since this is the environment in which challenges would present themselves, technical progress could be expected to consist largely of improvements at the labour-intensive end of the spectrum. Should this be cause for concern? That is, is this a likely outcome? And if so, should one worry about it.

In judging the likelihood of labour-intensive directed technical progress it should be noted that the view cited was originally advanced in a developed country context - and indeed as part of the continuing debate on the character of historical experience in the United States. It may consequently be less than fully relevant to developing countries where the capacity for research and development is anyway generally thought to be weak. Nevertheless, in so far as a capacity for research and development exists and/or can be developed,many would welcome an outcome that saw most of the effort devoted to improving and designing relatively labour-intensive techniques. Moreover, there is more to this than the missionary zeal of those who believe that small is always beautiful. In the circumstances of many poor countries labour-intensive processes would probably be more organically grounded than alternatives and so should develop more rapidly and more wholesomely in a number of directions. The use of such processes could create a large and rapidly growing artisan class and thus generate and sustain a demand for education of the kind that underlay the creation of the first technical colleges and mechanics' institutes in the now developed countries. If this demand were to be met it could have an impact, inter alia, on technical progress. In saying this it is necessary to recall that technical progress implies a saving in factor use, so that the presumption here is that there would be pressures to develop capital-saving techniques which it is assumed would also be labour-using but still, overall, cost reducing.

Given the above, there would seem to be little cause for dynamic concern if the international division of labour efficiently provides scope for the production of labour-intensive goods for domestic consumption and export in developing countries and if countries can readily enough move up the spectrum as circumstances change. Nevertheless, a stubborn critic might still confess to worry in the light of the electronics revolution that is widely thought to be upon us; and in the light of the speed with which that permanent revolution might proceed. Where, might the critic ask, is the scope for the labour-intensive in 'the factory of the future'? Where indeed is the scope for technically independent work-stations in the industrial process which computer-aided design, management and production has reduced to a continuously linked system of transforming inputs into outputs? One first response to these questions is another: where is the factory of the future, and when will it be a general phenomenon even in developed countries? Automation has not yet technically arrived, although it may come sooner rather than later. Technical feasibility is, however, one thing, successful commercial operation another; and there are reasons for thinking that the diffusion of automated techniques will take some time.[27] The markets for labour-intensive products are not going to disappear overnight. Nor is the making of 'sensible' choices of technique within a limited time horizon likely *per se* fatally to inhibit the ability of a country to adapt to changing conditions. The labour-intensive origins of recent and rapid growth in some of the newly-industrializing countries has not prevented them from preparing to 'up-grade' their technological base and their production techniques.

NOTES

1/ The density as well of the size of the range is important. If there were only two choices, one very capital- and one very labour-intensive, the range would be great but the choice inadequate. The need, as will be seen, is for well-populated sets of techniques capable of manufacturing given products.

2/ For a discussion of this question in the context of Ethiopia see James Pickett, Development, Technology and Employment in Ethiopia, DLI Discussion Paper No. 4, University of Strathclyde, Glasgow, 1984.

3/ The theory in question is the long run neo-classical theory of the firm. The convexity of the isoquant (viewed from the origin) derives from the fact that the contribution of each factor to production is subject to diminishing returns. Thus as capital is reduced the loss of output per unit of capital increases, whereas labour use increases the increase in output per unit of labour is falling. It follows that as substitution proceeds - beginning from a lot of capital, little labour - it will require more and more labour to 'compensate' for a unit of capital. It is also evident that, since the marginal rate of factor substitution measures the rate at which one factor is being substituted for another with output held constant, that the marginal rate of substitution between two factors must equal the ratio of their marginal products. The formal condition for profit maximization is $MP_K/MP_L = P_K/P_1$, where MP is marginal product, P stands for factor price and the subscripts have their obvious meaning. Given that the MRS at any point is the slope of the isoquant at that point, it can easily be seen that the condition is met - twice over - in Figure 1.

4/ Ignoring transport costs.

5/ For a discussion of engineering influence see Pickett et. al., "The Choice of Technology, Economic Efficiency and Employment in Developing Countries", World Development, March 1974 and the paper by Wells in Timmer et al, The Choice of Techniques in Developing Countries, HUP, 1975.

6/ For a fuller discussion, see A.K. Sen, Technology and Employment, OUP, 1975.

7/ For a breakdown of capital and other costs see, for example, Pickett and Robson, The Choice of Technology in the Production of Cotton Cloth, Scottish Academic Press, Edinburgh, 1982.

8/ Sir Austin Robinson in Robinson (ed.), Appropriate Technologies for Developing Countries, Macmillan, 1978.

9/ The definition does not seem to be Keynesian. It contains no mention of demand, nor indeed does the paper from which it is extracted. Perhaps the developing countries are assumed to be neo-classical price takers, though even that seems far-fetched in relation to, say, textiles and footwear.

10/ For other relevant calculations and discussions see Frances Stewart, Technology and Underdevelopment, Macmillan, 1977.

11/ This discussion draws heavily on the work of the David Livingstone Institute, notably the following monographs: D.J.C. Forsyth, The Choice of Sugar Technology, HMSO, 1979; N.S. McBain, The Choice of Technique in Footwear Manufacture, HMSO, June 1977; J. Keddie and W.H. Cleghorn, Brewing in Developing Countries, Scottish Academic Press, 1979; M.M. Huq and H. Aragaw, Choice of Technique in Leather Manufacture, Scottish Academic Press, 1981; J. Pickett and R. Robson, The Choice of Technology in the Production of Cotton Cloth, Scottish Academic Press, 1982; and B.A. Bhat and C.C. Prendergast, Choice of Technique in Iron Founding, Scottish Academic Press, 1984.

For broadly similar conclusions see Bhalla and for a still useful, more general review, White, "The Evidence on Appropriate Factor Proportions for Manufacturing in Less Developed Countries: A Survey", Economic Development and Cultural Change, October 1978.

12/ R.S. Eckaus, "The Factor-Proportions Problem in Underdeveloped Areas", American Economic Review, September 1955; W.E. Salter, Productivity and Technical Change, CUP, 1966; and Frances Stewart, op.cit.

13/ Pit looms were not included in the earlier discussion of textile alternatives which was confined to modern methods.

14/ For a fuller discussion see, Pickett and Robson, op.cit., Chapter IV.

15/ ibid. The prices used in this study were broadly market prices, but net of all taxes and subsidies. The UK 'project' was taken as marginal and the selling price set such that the NPV there (at a discount rate of 10 per cent) was zero. The study covered the latter part of the 1970s.

16/ Of 20/20 English counts.

17/ Doubling the discount rate would render production everywhere unprofitable, but would not alter the rank ordering. Since the calculations were constant cost ones, the 10 per cent rate already represents a stiff hurdle. It may be noted that the competitive advantage of the poor countries does not seem to spring from low wages (which are largely offset by low productivity) but rather from their ability to grow cotton. See Pickett and Robson, op.cit. Chapter VII. The calculations of Table 1 are based on a price of cloth which makes the UK least-cost mill marginal - i.e. gives a zero NPV.

18/ What follows is based on Bhat and Prendergast, op.cit., It should be noted that product mixes may vary greatly across foundries at any point in time and within foundries over time. However, in this study the analysis is of a homogeneous product.

19/ Forsyth, op.cit.

20/ For a fuller discussion of this see Pickett, Editorial Introduction, ibid. The finding in favour of the capital-intensive has itself been challenged. See Alpine and Pickett, "More on Appropriate Technology in Sugar Manufacturing", World Development, Volume 8, 1980.

21/ For a fuller discussion see Alpine and Pickett, op.cit.

22/ For an early attempt to document the character of choices of technique see R. Hal Mason, "Some Observations on the Choice of Technology by Multinational Firms in Developing Countries", Review of Economics and Statistics, 1973. For other relevant works,which stretch to explanation, see Timmer et al. and Pickett, et al., op.cit.

23/ For a further discussion see Pickett and Robson, Efficiency in Technology Choice in Leather and Sugar Manufacturing in Developing Countries, DLI Discussion Paper No. 1, University of Strathclyde, 1981.

24/ Particularly if the promotion of employment is given a prominent place, the discussion of industrial technique should stretch to cover adaptation and design as well as choice. To some extent work on all three fronts can, and should, proceed simultaneously. The view taken here, however, is that there is much to be said for concentrating most of the initial attention on improved choice. Consequently the policy discussion in the text does not, by and large, go beyond the improvement of choice.

25/ For an interesting comparison of the Philippines and Taiwan see G. Ranis, "Appropriate Technologies in the Dual Economy",in Sir A. Robinson, Appropriate Technologies for Third World Development, Macmillan, 1979.

26/ A useful, more extended discussion of this question is in N. Rosenberg, The Black Box: Technology and Economics, CUP, 1983, Chapter 1.

27/ As a supplement to this admittedly cavalier treatment of an important and complex topic, see Rosenberg, ibid, Chapter 9.

## Addendum

## Some Implications of 'Improved' Choice of Techniques and of Technical Progress

The purpose of these notes is to enlarge on an earlier paper[1/] by considering (a) some consequences of improved choice of industrial techniques, and (b) the implications for such choice of newly emerging techniques. These tasks are undertaken seriatim.

### I. Consequences of Improved Choice

If it be granted that developing countries now use techniques that are more capital-intensive than their factor endowments dictate (and that efficient, labour-intensive, techniques are available), it is natural to speculate on the consequences of better choice. Such speculation has not yet resulted in any large volume of systematic results. Part of the difficulty lies no doubt in the fact that the consequences it is desired to capture are by definition hypothetical. Moreover effort has largely gone into the logically prior task of demonstrating that efficient, more-or-less labour-intensive, options can be found.

The staunchest effort to date to elucidate the employment and other economic implications of better choice of technique has been made by Pack.[2/] Basing himself largely on the results of work done by the David Livingstone Institute, he has calculated the difference 'correct' choice would make in each of and in the aggregate of nine products - shoes, woven cloth, yarn, bricks, milled maize, processed sugar, beer, leather, and urea. The benefits are evaluated in terms of investment, value-added and employment, and are derived from a comparison of the

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1/ James Pickett, The Choice of Industrial Techniques in Developing Countries, May 1985.

2/ Howard Pack, Macroeconomic Implications of Factor Substitution in Industrial Processes, World Bank Staff Working Paper, No. 377, Washington, 1980.

characteristics of the most capital-intensive and the 'optimum' technique considered in each primary study. The 'optimum' technique is that which maximizes the ratio of net present value to capital (NPV/K).

The method used assumes that US $100 million is to be invested in each sector without changing either factor or final product prices. It is, moreover, claimed that the product mix is representative enough of that prevailing in the poorer LDCs. Plant size is taken in each case to be that which realizes technical economies of scale. Production, however, is taken as being highly divisible, so that US $100 million can be exactly exhausted in investment in both capital-intensive and 'appropriate' techniques in each sector.

The main results of Pack's calculations are set out in Table 1. These suggest that the benefits from improved choice would be considerable. To produce a given level of output the investible funds needed by the capital-intensive technique in each sector would be higher than those associated with the 'appropriate' one; and employment would be lower, so that the capital-labour ratio is generally higher in the capital-intensive mode. Given this, it is not surprising that US $100 million invested in each sector would give rise to significantly higher employment across the board if the 'appropriate' rather than the capital-intensive technique is chosen. Even in the generically capital-intensive business of making urea, the increase would be almost 12 per cent. The relatively labour-intensive technique would provide higher value-added and have a higher proportion accrue to capital than the alternative technique in each sector. Taking all sectors together, the use of 'appropriate' techniques in each would increase value added by 71.6 per cent and employment by 311 per cent.

TABLE 1: CHARACTERISTICS OF CAPITAL-INTENSIVE AND 'APPROPRIATE' TECHNIQUES IN PRODUCTION OF SELECTED PRODUCTS

| Product | Plant Size[a/] | Investment per Plant | | | | Annual Consequences of US $100 million investment | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|
| | | K | | K/L | | Value Added | | Non-labour income | | Employment | |
| | | A | B | A | B | A | B | A | B | A | B |
| | | US $000s | | | | US $000,000s | | | | numbers | |
| Shoes | 300,000 pairs | 165 | 334 | 0.8 | 2.2 | 88.99 | 68.12 | 73.19 | 59.04 | 31,589 | 18,158 |
| Woven Cloth | 40 million yds. | 4,715 | 9,779 | 8.7 | 37.6 | 23.44 | 4.80 | 18.20 | 3.61 | 10,488 | 2,538 |
| Cotton Yarn | 2,000 tonnes | 480 | 1,440 | 2.0 | 14.7 | 57.98 | 34.26 | 52.61 | 32.00 | 10,747 | 4,525 |
| Bricks | 16 million | 796 | 3,437 | 3.3 | 45.8 | 55.67 | -4.41 | 40.75 | -5.50 | 29,909 | 2,182 |
| Maize | 36,000 tonnes | 219 | 613 | 2.9 | 9.7 | 23.10 | 12.09 | 13.48 | 8.30 | 19,231 | 7,574 |
| Sugar | 50,000 tonnes | 3,882 | 6,386 | 0.8 | 6.2 | 247.66 | 162.80 | 185.68 | 154.84 | 123,980 | 15,925 |
| Beer | 200,000 hecto-litres | 2,809 | 4,512 | 12.1 | 18.3 | 52.39 | 23.89 | 48.66 | 21.73 | 7,460 | 4,316 |
| Leather | 600,000 hides | 4,832 | 6,692 | 15.5 | 36.2 | 19.74 | 11.77 | 17.49 | 10.72 | 4,502 | 2,108 |
| Urea | 528,000 tonnes | 29,597 | 34,132 | 122.3 | 137.6 | 54.95 | 50.11 | 54.57 | 49.76 | 772 | 691 |
| All | - | 47,495 | 67,325 | 6.68 | 28.52 | 623.92 | 363.51 | 504.60 | 334.50 | 238,678 | 58,017 |

Legend: A = Capital-Intensive

B = 'Appropriate'

Source: Pack. *op.cit.*, Tables 2 and 3.

a/ Annual Output.

The industry studies on which Pack largely draws (and others on which he does not) carry the implication that the choice of technique could be improved in ways that would save on the use of investible funds, generate more employment and either increase profitability or at least require marginal sacrifice in this regard. If more careful scrutiny could be introduced, benefit would follow. This much, to repeat, is clear from the industry studies. Does Pack's attempt to calculate the macro-economic gains take matters much further? In this regard it has to be said that the calculations are subject to powerful reservations. Pack himself recognizes that the 'wrong' techniques chosen do not necessarily lie, as it were, right at the capital-intensive end of the spectrum, so that gains are maximum ones. He also recognizes, rather casually, that value added (at least by labour) through better choice would have to be diminished by the opportunity cost of the extra workers in the selected sectors. There are, however, other reservations.

It may be doubted if casual simulation will really serve in such complex circumstances. Moreover, the definition of the 'appropriate' technique (NPV/K) derives its justification from an artificially-imposed capital rationing constraint - and even then it is difficult to give formal justification for it.[3/] Again, the Strathclyde studies used by Pack do not identify the technically optimum size of plant.[4/]

## II. Emerging Techniques

It is widely - if not always correctly - supposed that developing countries have a comparative advantage in the use of labour-intensive techniques, since they enjoy lower

3/ For a fuller discussion of this, see Pickett, Report on a Pilot Investigation of the Choice of Technology in Developing Countries, Glasgow, 1975, Chapter 3.

4/ Ironically the one Strathclyde study which does - textiles - is not used by Pack.

labour costs. If the processes of which this is now true were to be automated in the developed countries, would this lead to a switch in comparative advantage? This question illustrates the kind of fear that is expressed on behalf of the developing countries about technical progress. Unfortunately little systematic investigation has been made of the basis for this fear.

That significant changes - affecting not only industry, but also agriculture and services - are afoot cannot be gainsaid. The microelectronic production, processing, transmission and storage of information is having a marked impact on industrial processes. In some cases it has led to reductions in labour costs, improved management, better product design and quality control, and so, it would seem, threatened developing countries using conventional techniques, low labour costs and abundant natural resources - in textiles and leather goods for example. The gains from natural abundance are further threatened by developments in material technologies - the substitution, for example, of optical fibres for copper in telecommunications is not evidently good news for Zambia and Zaire.

It is, however, wrong to see only threat in the new techniques. Some LDCs - such as South Korea and Taiwan - may more easily, given their institutional framework and relatively docile labour forces, effectively exploit the new opportunities than some at least of the developed market economies. And some of the new products and materials required may be suitable for LDC production. It is probably too early to draw up a balance sheet in these regards. This is particularly true of biotechnologies - based on developments in molecular biology, biochemistry and genetics - since by and large these have not yet moved from the laboratory to the point of production.

June 1985