Non-Agricultural Choice of Technique: An Annotated Bibliography of Empirical Studies

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BY GARETH JENKINS

With an Introduction by Frances Stewart

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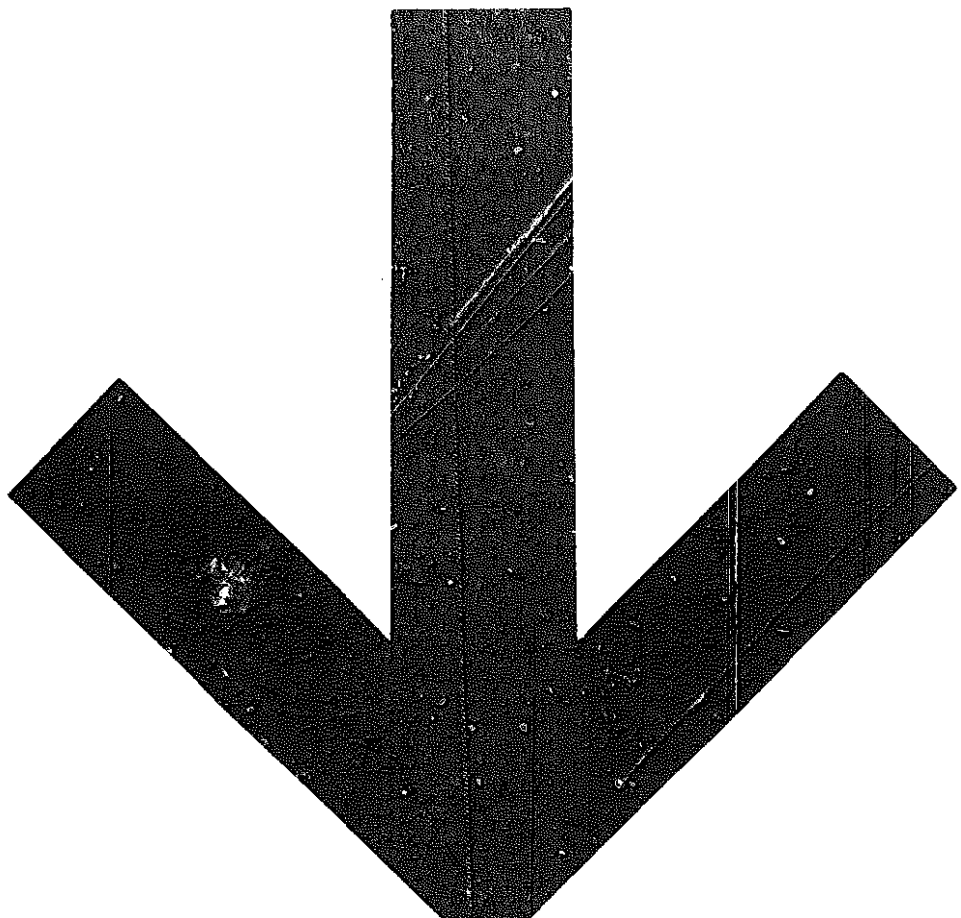

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INTRODUCTION[1]

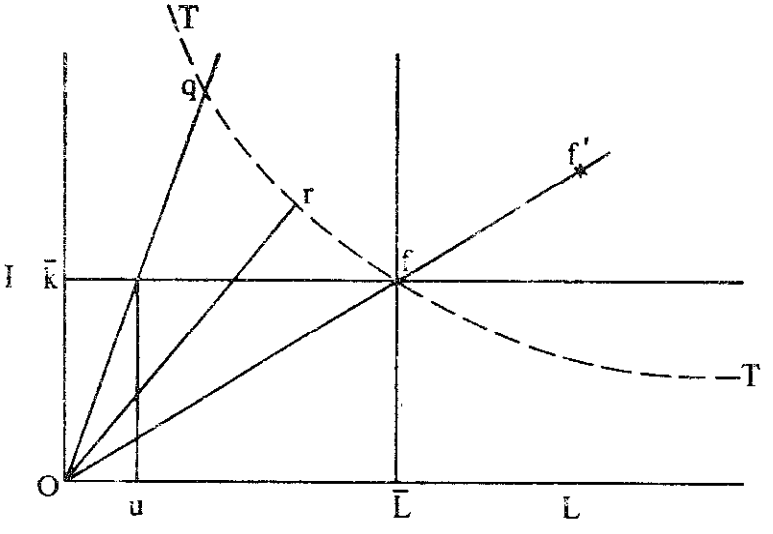
THE main aim of this bibliography is to provide an annotated guide to empirical studies on the question of choice of technique in developing countries. The key importance of the question of the nature and extent of technical choice available to developing countries has long been recognized, from both a theoretical and a practical point of view. Neo-classical analysis of choice of technique (and the broader questions of economic growth in which choice of technique is subsumed—see Hahn and Matthews [5, 1965]) is premised on the existence of a wide range of different techniques of varying labour- and capital-intensity to produce a given output. The debate as to whether capital-intensity may be justified even in a labour-abundant economy because of the consequences for savings and subsequent growth (see Galenson–Leibenstein [4, 1955], Dobb [3, 1956–7], *Sen* (1968) and criticisms of this position, e.g. Stewart and Streeten [14, 1971]) is of relevance only to the extent that there does in fact exist a choice of technique. Critics of the neo-classical view have denied that such a choice exists. (See Amin [1, 1969] and Kaldor [8, 1965].) Policy recommendations for changed factor prices in developing countries, which appear with predictable regularity in economists' reports, are in most cases derived, implicitly or explicitly, from models of development which assume the existence of such a choice.

We may illustrate the significance of the question by using a simple diagram. Suppose the economy produces a single good. Suppose that it has limited investment resources,[2] as shown by $O\bar{k}$ in the diagram, and that it has labour supplies $O\bar{L}$. For full employment of labour and full use of its investment resources the appropriate technique is represented by f in the diagram. The investment per man is shown by the slope of the line Of, which may be defined as the capital- or investment-intensity of the technique. If there is a wide range of efficient techniques for

[1] In the introduction many of the references are to entries in the bibliography. These are italicized (and dated where more than one entry by any author is included in the bibliography). References in the introduction to works which do *not* appear subsequently in the bibliography are followed by square-bracketed numbers and date of publication, but they are not annotated. The square-bracketed references are listed in full at the end of the introduction.

[2] The period of time covered by 'investment resources' depends on the length of life of the capital equipment. If the equipment only lasts one year then the whole labour force has to be re-equipped every year, and investment resources relate to a single year. The appropriate period over which to measure the investment resources is thus the typical length of life of capital equipment. Where (as is normal) this exceeds a year this presents problems of aggregation over time; the total investment resources available then varies with the interest rate used for aggregation.

producing the good in question, as shown by the isoquant TT in the diagram, then the existence of appropriate technique f is assured. The question at issue is then whether to adopt technique f thereby ensuring current full employment, or whether by using a more capital-intensive technique, say r, more savings may be generated and subsequently a faster growth in investible resources and output and employment. Practically, the question at issue is how to alter factor prices and other determinants of technique selection in such a way that the appropriate technique, be it r or f, will in fact be selected. But suppose the isoquant



TT is a figment of the economists' imagination and only a single efficient technique exists, shown by the ray Oq. Changing factor prices and other incentives to secure the adoption of technique f will then be pointless, since being the only available technique q must be chosen. The debate between f and r is equally pointless. Unemployment $u\bar{L}$ is inevitable.

Recently the claims of those who advocate 'Intermediate Technology' (I.T.) (see *Schumacher* (1965)) have been receiving increasing attention. In criticizing the I.T. claims it has been argued, firstly, that such a technology is an inferior technology, in the sense that it involves lower levels of output for any given investment expenditure; and secondly, that it involves lower levels of savings and hence of growth. Both these criticisms are part of the familiar debate about technology. In terms of the diagram the I.T. enthusiasts can be seen as arguing that f exists and should be adopted, while the critics argue *either* that to the extent that low I/L techniques exist (and I.T. advocates hold out concrete examples, so for some areas that cannot be denied) their productivity is low and the position on the diagram is f' rather than f, involving a loss in output for any given investment as compared with r; *or*, in so far as f does exist, r should be chosen in preference on account of the savings factor.

If savings vary with the technique chosen then the technique adopted, the point chosen on isoquant TT, affects the rate of growth of resources, savings, investment, output, and employment. I.T. advocates might deny that their claims can be so easily fitted into the old debate. To some extent they are right, in that they are discussing the creation of a new technology, rather than the existence of an old one. Thus they have introduced, correctly, a dynamic note to the debate. Moreover, they are concerned with many aspects of technology not represented in this diagram, e.g. income distribution, rural/urban questions, etc.—see *Schumacher* (1965 and 1973). None the less a rational assessment of the I.T. case does require, as a prerequisite even if it would not contain the ultimate answer, factual knowledge as to how I.T. techniques compare, in terms of investment and labour productivity, and surplus generation, with more conventional techniques.

Fruitful discussion of the choice of technique in an economy thus requires factual knowledge about the range of techniques available and the investible surplus generated by them. Most theoretical work, and much work on policy, is written in partial or complete ignorance of such facts. It is therefore the aim of this bibliography to collect together the empirical work that has been done in this field.

The model depicted above is extremely, indeed perhaps distortingly, oversimplified. It side-steps the manifold problems raised by the concepts of *capital* and *capital-intensity* using instead *investible resources* and *investment-intensity*, though these concepts are by no means problem-free either. (Some of the difficulties are discussed in *Boon* (1964) and *Stewart*.) It assumes there are only two scarce factors, homogeneous labour and capital. Shortages of other inputs—e.g. skilled labour or management—may make the model irrelevant. Another objection to the I.T. case is that it may make more use of scarce managerial and administrative resources than other less labour-intensive techniques. It assumes (though this is not of critical importance) that the concept 'full employment' is meaningful and identifiable. It ignores scale as a factor determining the nature and efficiency of techniques. It is static, in the sense that it looks at technology at a moment in time, whereas technology is continuously changing. And, perhaps the most significant weakness, it is postulated on a single-product world. Product choice is an important dimension of choice in a number of ways. In an open economy, choice of product and specialization through trade allow for variations in investment- and labour-intensity even where each product is associated with a unique technique. For domestic consumption the same needs may be fulfilled by different products (in nature or quality) thus widening the range of technology available (see Stewart [15, 1972]).

Some of the empirical studies share the weakness of the model; others do not, and illuminate dimensions of technical choice not contained in

the simple one-good, two-factor model. Broadly two approaches have been adopted. First, the macro-approach of fitting production functions (of a constant elasticity of substitution (C.E.S.) type) to cross-section data within an industry, and sometimes between industries. This approach was pioneered by *Arrow, Chenery, Minhas, and Solow*. The approach suffers from the conceptual defects of C.E.S. production functions. In general, vintages are ignored and machinery of widely differing age and origin is treated as if it were all part of a single production function. Capital is treated as a homogeneous input, and its marginal product is assumed to be given by the profit rate (while similarly the marginal products of other factors, like labour, are also assumed to be given by their rewards). Given these (and other) assumptions the production function which best fits data is calculated, and the elasticity of substitution between factors derived. The elasticities so derived are as much a derivative of the (artificial) assumptions made as of the data, and do not, we believe, shed much light on current opportunities of developing countries. Some references to this type of work have been included in this bibliography (see Section 3) but we have not aimed to be comprehensive. The approach is subject to systematic criticism by *O'Herlihy*, and also by Harcourt [6, 1972]. *Morawetz* shows the inconsistency between the industry ranking generated by different studies using the C.E.S. approach. See also *Dhrymes* for discussion of the various concepts employed in such an approach.

The second approach is that of the micro-studies. These look at the required inputs to produce a given output—normally a single product, or very close substitutes. These are contained in Section 1 of the bibliography; here we have tried to be comprehensive, outside agriculture. We have not included studies of agricultural techniques. Not all the studies fall neatly into one or other of our two categories. Some (see, for example, *Diaz-Alejandro* (1972)) collect data at a micro level and then apply production function techniques to the data so obtained. The micro-studies tend to be particularly subject to two defects: first, to avoid problems of product valuation they generally aim to cover only techniques which result in the same or extremely similar products. They thus fail to pick up possible choice of technology via choice of products. For example, *Stewart* looks at different methods of producing cement blocks. As far as choice of technique is concerned there is probably much more difference between the labour- and investment-intensity of methods of producing cement blocks, mud-bricks, and stones (all alternatives for housebuilding) than between different methods of producing blocks. The wide variations in performance between examples of the same technique, shown by *Stewart* and *Doyle*, suggest that studies which take only a single example of each technique may be defective. The second major weakness of the micro-studies is their

static nature. This means that the studies become obsolete as fast as the machines under examination.

Each of the studies is in some ways time and country specific and the results cannot be generalized. They are country specific for two reasons: first because technical requirements may vary between countries because of differences in geography, managerial skill, and raw-material resources. But even with identical technical characteristics, economic differences may lead to differences in investment and other costs. To calculate investment costs requires estimating and adding up the costs of building (local labour and local machinery) and the costs of machinery, which may be produced locally or imported. In addition, for comparisons between techniques, repair and maintenance costs, and differences in lengths of life of assets must all be considered. Putting figures on these items involves adding up non-homogeneous items, and hence evaluation (e.g. of the value of building costs as against imported machinery). But once one does this one has introduced economic variables, not just technical. While empirical case studies of the choice of technique generally try to stick to technical values as much as possible, all the studies, to varying degrees, make use of economic data as well. Some in fact go the whole hog and convert the exercise to one of cost-benefit analysis (see *Pickett*). It must therefore be emphasized that apparently technical ratios comparing I/L, I/O[1] for different techniques are based in part on the conversion of non-monetary (technical) values into money values. This inevitably involves some assessment (implicit or explicit) of the relative value of different items, and consequently the ratios may be altered by a different relative valuation.

Reference has already been made, in passing, to the recent severe and penetrating attacks on the concept of *capital*. (See Harcourt [6, 1972] for full bibliography and Sen [13, 1973] for an amusing review of the debate of relevance to the discussion here.) It has been shown that there is no objective entity *capital* which may be uniquely measured in the way that one might count pebbles on a beach. The capital stock consists of heterogeneous items produced at different times, with different lengths of life. Summing these involves weighting, and the particular sum arrived at—the 'quantity of capital'—depends on the weighting used, and in particular on the time-weighting, or the rate of interest. Thus neither the quantity of capital, nor the marginal product of capital are objectively identifiable, which was one of the chief reasons for criticizing the C.E.S. approach. It might be thought that the concepts of capital- or investment-intensity—at the heart of the studies

[1] Here and in what follows,

I = investment cost
L = employment
O = output

compiled here—was, by the same token, weakened. However, these studies are, at best, concerned with the investment costs of different techniques, not with the capital stock. That is, they do not try to aggregate the value of past investments, but rather look at the current investment costs of introducing different techniques. Some weighting is involved here because investment decisions too involve non-homogeneous items, over time as well as across time. With assets of different lives, the interest rate assumed will influence the values reached. Thus the investment costs of the techniques are not immutable quantities, but are, as argued above, dependent on the various systems of weighting adopted. This does not invalidate the studies: they are necessary inputs for making investment decisions, and for realistic discussion of the theory of technical choice. But it does mean that the investment-intensity (and the other associated ratios) of any technique is dependent on the value of the weights adopted, and is not objective and unalterable. Some of the studies collected here show themselves more aware of their tentative and non-objective status than others.

Besides the macro and micro work of direct relevance to the question of choice of technique we have also included any works we have come across that contain information on capital– or investment–labour ratios and capital– or investment–output ratios (in Section 2). See, for example, *Bhatt*, *Creamer*, and *Mehta*. We have a small (and non-comprehensive) section on small-scale industry (Section 4), including those studies which are directly concerned with choice of techniques, and a few others. As argued above, most of these studies tend to be static, taking no account of technical change. As a complement therefore we have included (in Section 6) some studies of sources of technical innovation in developing countries (see, for example, *Aurora and Morehouse*). We have also some items on technical choice in Japan and China. Both provide information of relevance to the large-scale/small-scale debate, and to the question of source of technical innovation in a dynamic and developing society.

Apart from the references to this introduction this bibliography does not include purely theoretical works. It covers only work published in English, and a systematic search for material was ended at the end of 1972 (publication date), though we have included some items beyond that date. We have included mimeographed material where it has been known to us.

For readers' convenience we have divided the entries into seven sections. The items are not always easily classifiable and to some extent the division is rather arbitrary. Despite the fact that some entries qualify for more than one section, we have entered each only once. The final section (Section 7) contains tests of theoretical hypotheses (e.g. the Galenson–Leibenstein hypothesis). It is also a miscellaneous section for entries that do not fit in elsewhere.

Some conclusions

Since the bibliography contains fairly extensive notes on each entry, we shall not attempt to provide a summary of either methodology or findings. Here we note some of the conclusions, without pretending to be comprehensive. Most of the case studies found that, in some sense, there did exist a range of technically efficient techniques in the industries examined.[1] To some extent this finding was the result of the choice of industry since extensive case studies were, it is likely, only initiated for industries where there was a presumption that such a range of techniques did exist. However, the phrase 'in some sense' is important. The conclusion that a neo-classical array of techniques is available has to be qualified in the following ways. Many of the studies showed variations in the nature and quality of the products as between different techniques, and consequently product considerations could determine technique choice. Thus *Baron* shows that production of the traditional Indian sweeteners (gur and khandsari) is both more capital-saving and more employment-creating than either of the two techniques for manufacturing white crystal sugar. *Stewart* finds that the creation of consumer demand for sophisticated maize products gives rise to more capital-intensive grinding techniques; while in block manufacture the demand for products of a certain quality dictates the use of a more sophisticated technology for their manufacture. *IBRD* makes a similar point with reference to road construction, *Bhalla and Gaude* (service industries), *Kilby* (1965) (bread), *Gouverneur* (extractive industries), and *Pfeffermann* with reference to manufacturing in general. In the study by *Wells*, however, this factor is discounted, it being argued that quality differences in the Indonesian industries investigated were slight and not generally perceived.

Economies of scale. Techniques are not perfectly divisible and a definite tendency was found for the more capital-intensive techniques to be designed for a larger scale than the labour-intensive. This arises in part from the historical stage of development at which the different techniques were developed. Generally speaking the small-scale techniques originate from an earlier historical period, when investment resources, in relation to the labour supply, were less abundant. Thus comparisons between techniques were found to be more favourable to

[1] Techniques are described as technically efficient if for any given output level, in relation to each other, the use of more of one factor is associated with the use of less of some other factor. A technique is said to be technically inefficient or inferior if it uses more of each factor to produce a given output. Technical efficiency is a necessary but not a sufficient condition for economic efficiency. An economically efficient technique is one which minimizes cost—private or social depending on the point of view adopted. Economic efficiency thus depends on technical factors *and* on economic variables, particularly prices, though as argued above one cannot in fact define the technical factors independently of economic variables.

the labour-intensive alternatives at small scales of production, while these were often ruled out becoming inefficient, at large scale. The many extensive studies by *Bo'n* support this conclusion. See also *Bhalla and Gaude* and *Stewart*.

Capacity utilization was found to be of significance in two studies. *Bhalla* (1965) attributes the superiority of the most capital-intensive rice-processing techniques studied to this factor, and *Stewart* likewise emphasizes that systematically low capacity utilization was a serious handicap to certain of the maize-grinding and cement-block-making techniques studied.

From a theoretical point of view labour-intensive technologies are likely to be used less fully (see *ILO* (1972) and Marris [9, 1964]). The pattern of consumer demand and entrepreneurial opportunity can also bring about different degrees of capacity utilization between techniques.

Bhalla and Gaude, *Prasad* and *Sen* (1968) all emphasize the importance of working-capital requirements, which in general are proportionately less for more capital-intensive techniques. The importance of working capital in relation to net value added in various sectors of the Indian economy is estimated in *Sen* (1964).

Many of the studies that did identify a range of efficient techniques found that the labour productivity of the more labour-intensive methods was extremely low as compared with the capital-intensive techniques, so that they would only be economically justifiable at extremely low wages. This was a factor in the studies on earth moving (*Dreiblatt* and *UNDESA* (1960, block making, and can sealing). The Ambar Charkha (see *Economic Weekly*) required a wage subsidy of 80 per cent.

Related to the question of low labour productivity, three works attempt to test the Hirschman hypothesis—that the difference between labour productivity in developed and developing countries would be greatest for labour-intensive activities and least for capital-intensive. (See *Hirschman*, *Gouverneur*, *Healey*, and *Diaz-Alejandro* (1965).) While each found a number of exceptions, the evidence on the whole did support the Hirschman hypothesis.

The Hirschman hypothesis is based on the assumption that more management and supervision is needed for labour-intensive than for capital-intensive activities, that this is (relatively) scarce in LDCs, and consequently discrepancies between labour productivity are greatest in labour-intensive activities. The hypothesis thus takes us away from the simple two-factor approach which is the basis of conventional analysis. Other studies, in a similar way, emphasize managerial and supervisory labour, arguing that capital equipment may substitute for such (scarce) labour as well as for unskilled labour. This was found to be a significant factor in can sealing (*ILO* (1972)). *Hal Mason*, *ILO* (1972), and *Pack* argue, with supporting evidence, that foreign firms tend to have easier

access to managerial talent and therefore tend to substitute managers and supervisors for capital equipment as compared with local firms. When comparing capital-intensity of similar-size firms producing similar products, they each found that foreign firms tend to be less capital-intensive. This appears to be in strong contrast to the widely held presumption (supported by evidence in *Pfeffermann* and *Wells*) that local firms are more labour-intensive than foreign firms. Part of the explanation of this conflicting evidence is that foreign firms are generally concerned with producing products which require a more capital-intensive technology, and do so at a larger scale than local firms, typically, which in part accounts for their over-all impact being to raise capital-intensity (see *ILO* (1972) and *Hal Mason*). *Wells* attributes the greater capital-intensity which he finds among foreign firms partly to the higher wages they pay (though the causal nexus could just as well go in the other direction), and partly to economically irrational preferences of foreign managers for capital-intensive techniques. Foreign firms do often face a different set of prices and constraints from local firms, which could account for divergencies in either direction.

Wells and *Pickett* bring to the fore a central question—viz. the economic rationality of the entrepreneur. Both argue that the choice of capital-intensive techniques is not justified from a private profit maximization point of view, and thus attribute the choice of such techniques to irrational 'engineering man'. (The *Pickett* 'irrational' choice was derived by comparing the actual choice with hypothetical labour-intensive alternatives which, though based on actual techniques, may well not have been known to the entrepreneur. Thus ignorance and the costs of search must also be included as possible determinants of technical choice.) In strong contrast other studies find the choices rational from a private point of view, if dubious for society as a whole. (See *ILO* (1972), *Baron*, *Kilby* (1965 and 1969), and *Stewart*.) *Granick* also finds some of the Soviet choice of technique in metal working economically irrational, though in the opposite way from that of the other studies substituting labour for capital, when labour was relatively scarce. One could draw interesting ideological conclusions from these opposing tendencies of the two systems.

Monopolistic factors were held responsible for a relatively capital-intensive choice by *Wells*, *Kilby* (1969), and *Pfeffermann*.

Some of the studies distinguished between different stages in the productive process. In general, it was found that the scope for labour-intensive activity was greater for ancillary activities (transport, preparation of materials, and packing) than for the core process or activity. Many developing countries do use labour-intensive methods for these ancillary processes, while using the conventional capital-intensive techniques for the core process. (See *Granick*, *Kilby* (1965), *Pack*, *Johnson*,

and *Ranis* (1957). For many goods the core activities account for only a small proportion of the total employment or costs: in beer the cost of manufacture is only 10 per cent of the ex-factory price (*Kilby* (1969)).

Many blueprint-type exercises appear to neglect possibilities of combining strategies, with some stages of production carried out in a labour-intensive way and others in a capital-intensive. (See *Müller* (1973).) The road-construction/earth-moving studies emphasize the economic benefits of a mixed strategy.

The surplus maximization/current output maximization debate on choice of technique is treated empirically by *Sen* (1968), *Stewart*, *Ranis* (1962), *Sandesara*, and *Mehta* (1969). *Bhalla* (1964) finds that the greatest surplus per person employed is generated in small plants. *Ranis* (1962), however, finds that surplus is maximized in medium-size plants. *Sandesara* distinguishes between labour-intensity and scale. He finds that large-scale labour-intensive technology maximizes surplus and output per unit of investment in the industries examined. In contrast *Mehta*, (1969) and (1972), finds no systematic correlation between operating profits by industry group and capital-intensity. A number of authors question the empirical basis of the Galenson–Leibenstein assumption of a uniform wage, as between different techniques. The evidence all suggests that labour-intensive and small-scale activities pay lower wages. (See *Bhalla* (1964), *Stewart*, *Sandesara*, *Shetty*, *UNIDO* (1964), *Okita* (1961).)

While most of the studies are designed to look at the range of choice at a given point of time, some throw light on trends in technical choice over time. This is one of the main elements in *Salter*'s classic work. *Gouverneur* follows Salter's methodology in looking at trends in capital intensity in some firms in the Congo. These data, some on Japan (see *UNIDO* (1964)), and other data not collected here, show, with few exceptions, an increase in the capital–labour ratio over time. Movements in the capital–output ratio are more ambiguous. (See, for example, *Creamer*.) This historic dimension, ignored in the case studies, is of great importance in thinking about likely developments in technical choice.

We have included some articles which discuss technological innovation in developing countries, notably *Aurora and Morehouse*, *Giral and Morgan*, *Bourke*, *ITDG*, *Judet*, *Nayudamma*, and *Sanson*.

Small-scale industry

As argued above, scale and labour-intensity are often related, with the large scale being of greater capital-intensity than the small. While this in part reflects the historical date of introduction of the technology and the trends in industrial concentration (see, for example, Pratten [10, 1971], Armstrong and Silberston [2, 1965], and Sawyer [11, 1971]) it is also likely that technical indivisibilities are such that the large-scale

machines require proportionately less labour than do smaller. This being so, there tends to be confusion between scale and labour-intensity in discussion of techniques; some features which are to be associated with techniques because they are used on a small scale tend to be attributed to their labour-intensive nature and vice-versa. Of the authors here only *Sandesara* and *Boon* make systematic attempts to sort out those features related to scale, and those to labour- and capital-intensity. Much of the literature on small-scale industry is of direct or indirect relevance to the question of choice of technique because of this association. Here we select those items which appear to be most obviously of relevance.

Dhar and Lydall stress that modern small industries, without extensive infrastructural development, are not appropriate as instruments of decentralization since they rely heavily on external economies. They also argue that small enterprises generate lower wages and profits per unit of capital than large enterprises, though they tend to have lower capital–output ratios. *Sandesara* agrees that small enterprises generate low surplus per unit of capital and are associated with low wages, but argues that they also have a high capital–output ratio, a high labour–output ratio, and are not necessarily labour-intensive. However, labour-intensive units (often large-scale) have a relatively low capital–output ratio and high surplus–capital ratio. *B. V. Mehta* (1969) disagrees with his method and many of his conclusions. *Aubrey* considers small-scale enterprises can help save investible resources and augment local employment and incomes, and that they are particularly suited to short production runs, to conditions of fluctuating demand, and for the manufacture of quality and non-standardized products. NCAER finds that in India I/L and O/L ratios rise and O/I falls as the size of the enterprise increases. *Shetty*, comparing small-scale industries with household industries, finds that I/L and O/L were higher among small-scale industries, while I/O ratios were similar; wages were generally lower among household industries; surplus per unit of investment was none the less higher among small-scale industries. *Staley and Morse* demonstrate that small plants in U.S.A. and Japan tend to have a low capital–output ratio and also a low fixed capital–labour ratio. *UNIDO* (1969) argues that small Japanese plants have low capital–labour ratios and low wage rates, but finds no systematic correlation with the capital–output ratio. In India small size is generally associated with low labour productivity, but in Pakistan this is less frequently the case.

UNIDO (1969) investigates the advantages of sub-contracting in the manufacture of bicycles, while *Foster and Wood* demonstrate that locational factors, in the Indian context at least, can substantially favour the installation of small-scale fertilizer plants. *Vepa* surveys the role of small industries around the world.

Japan and China

Japan and China are two countries which, in different ways, have benefited from a dualistic approach to industrial development, 'walking on two legs', combining modern large-scale and capital-intensive technology in one sector with small-scale labour-intensive technology in the other. Here we have collected together only a small selection from the growing literature on the subject.

Ando, Okita (1964), and *Watanabe* (1971) deal specifically with the sub-contracting system, *Okita* (1964) giving a detailed analysis of the size-structure of Japanese industry. *Watanabe* (1970) emphasizes the very low capital requirements to set up as a manufacturer, and the widespread use of second-hand machinery. *Ranis* (1957) points out that technique choice in Japan was highly discriminatory, noting the absence of cottage industries from cotton spinning where the most modern methods were much more efficient. *Johnston* discusses the deliberate encouragement of dualism by the Japanese government, and the importance to its success of a strong demand for traditional products, good communications, established cultural values which permitted the sub-contracting system, and the complementarity of small manufacturing enterprises and agriculture.

The dualistic nature of technical choice in China is brought out by the studies. *Dean* discusses the way in which a balance has gradually been achieved between practical innovation and innovation by experts in developing the technical skills necessary for innovation. *Sigurdson* (1974) analyses the small-scale local industries of one province, and in particular the development of small-scale plants for the production of cement for projects where a very high quality is not required. *Riskin* discusses the principle of complementarity between local industry and agriculture on the one hand, and local industry and central industry on the other, and the way in which conflicts between these two sectors of industry have gradually been resolved—'use steel only for the cutting edge of a knife'.

The political economy of technical choice: the neo-classical framework in which choice of technique is most often considered, as in most of this introduction, and many of the case studies considered here, apparently removes the question from the realm of political choice into that of technical facts and economic realities—the former providing the range of choice, the latter, via prices, determining the selection. But the question of choice of technique is of central importance in determining the nature of what is produced and its distribution. Indeed, it also helps determine the distribution of income and power between nations, as well as within nations, since the national origin of the technology determines the flow of payments for the technology, while the ownership of assets

tends partially at least to reflect the national origin of technology used. Choice of technology is thus at the heart of many of the key questions of political economy. The neo-classical framework tends to mask this. Some of the studies indirectly reflected on this—for example *Sachs* lists subsidized credit, fiscal rebates, high inflation, labour taxes, and labour unrest as responsible for choice of capital-intensive technology; *Strassman* adds redundancy payments, 'high' wage rates, and tax incentives to reinvest profits. Discussing Senegal, *Pfeffermann* emphasizes factors which favour foreign-owned enterprises which thus come to dominate certain sectors, especially discrimination in the markets for capital and labour. *Baron* discusses the influence of vested interests in Indian sugar manufacture, *Timmer* blames international consultants for making inappropriate choices of rice-processing equipment for Indonesia. *Stewart* emphasizes the influence of income distribution on the type of products for which there is a market. At a macro-level *Merhav* and Stewart [16, 1974] explore some of the implications of technological dependence for the third world.

At a micro-level, many of the factors determining choice of techniques are accepted as given for the purpose of the studies. These variables appear to be determined by impersonal and uncontrolled forces which set the constraints within which choices must be made. In particular, the available range of technology (and its price), the availability of different factors of production and income distribution, and markets are taken as given, while only factor prices are regarded as alterable by policy. While, at a single point of time, this approach may be legitimate, it hides the fact that the range of technological choice and the availability of factors of production are themselves the result of human decisions. Income distribution is both part cause and part product of technical choice. In the long run, the choice of technique may be transformed by action on these fronts rather than on the conventionally accepted factor-price frontier. The need is to devise studies which shed light on these possibilities.

FRANCES STEWART

February 1974

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SECTION 1

Industry case studies of choice of techniques

ASIAN INDUSTRIAL SURVEY FOR REGIONAL CO-OPERATION: *Proposal for Regional Co-operation in the Production of Salt and Its Derivatives*, Study No. 9, prepared by Dr. J. L. Enos, Bangkok, March 1973.

Investigates three techniques for the production of high-grade salt for industrial use. One highly labour-intensive technique—found especially in Indonesia—was not considered, both because of a lack of data and because such a mode of operation would not be possible on a large scale. The three technologies compared are: solar evaporation of sea-water, first using traditional methods and secondly mechanical methods, and production by a vacuum pan method using rock salt from mine or pond; rock salt could also be used in the first two processes.

Comparisons were made for production in Sri Lanka, as possessing an industry well equipped to cope with a large expansion of output. The major characteristics of the three processes for an output of 150,000 metric tons per year are given in the following table, valuing salt at U.S. $8·41 per ton; estimates are also given in the text for production at 600,000 tons per year and 2,100,000 tons per year in the case of the two more labour-intensive techniques:

	Partially mechanized (labour-intensive)	Fully mechanized (intermediate)	Vacuum pans (capital-intensive)
Fixed capital (U.S. $million)	4·97	5·15	7·10
Employment (jobs)	893	364	250
Av. output cost (U.S. $ per ton)	8·41	8·55	18·50
I/O ratio ($/$ per year)	4·0	4·1	5·6
L/O ratio (jobs/000 tons)	6·0	2·4	1·7
I/L ratio ($/job)	5,600	14,100	28,400

The report suggests that were shadow prices for inputs calculated, then the labour-intensive technique would display considerably lower unit costs of production than the intermediate technique.

The report further considers questions of scale and location within S.E. Asia.

BAER, W.: *The Development of the Brazilian Steel Industry*, Vanderbilt University Press, 1969, pp. 17–20.

The author found that even in processes where in theory technological choices exist—in the steel shop, the workshop, the foundry, and in materials handling—there was little noticeable substitution of labour for capital. The reasons given were in terms of the insignificance of labour costs compared with value added, and of the need to avoid bottlenecks. An expanding industry is likely at some stage to introduce a continuous casting system to replace the ingot preparation and casting stage in the steel shop and the initial process of blooming or slabbing in the rolling-mill. This would further reduce employment.

BHALLA, A. S.: 'Investment Allocation and Technological Choice—A Case of Cotton Spinning Techniques', *Economic Journal*, September 1964, pp. 611–22.

This is one of a number of articles on Indian cotton spinning (see also entries for *Economic Weekly*, and for A. K. Sen, *Choice of Techniques*). The ordinary charkha, the Ambar Charkha, and the factory spindle are compared and the author concludes that there is a case for the ordinary charkha in terms of output and employment objectives, and for the factory spindle in terms of reinvestible surplus, but not for the intermediate technique of the Ambar Charkha.

On the basis of various wage, depreciation, and savings assumptions the author calculates a range of values for the relevant coefficients. Estimates of the capital–output ratio range between 0·4 and 0·8 for the ordinary charkha, between 1·0 and 1·4 for the Ambar Charkha, and between 0·8 and 1·0 for the factory spindle. The range of values for capital–value added is 1·6–6·6 for the ordinary charkha, 3·8–11·8 for the Ambar Charkha, and 2·9–8·6 for the factory spindle. The range for capital–labour is 0·5–0·1 for the ordinary charkha, 0·2–0·3 for the Ambar Charkha, and 16·1–22·1 for the factory spindle. The range for surplus–capital is 0·6–3·7 per cent for the ordinary charkha, 0·3–1·5 per cent for the Ambar Charkha, and 13·3 per cent for the factory spindle.

See also the entry for D. R. Campbell.

BHALLA, A. S.: 'Choosing Techniques: Handpounding Versus Machine-Milling of Rice: An Indian Case', *Oxford Economic Papers*, N.S. vol. 17 (1965), pp. 147–57.

Concludes from a study of five handpounding and three machine-milling techniques that while investment in hand techniques (as proposed in the second Indian Five Year Plan) would keep capital and labour occupied, it would not contribute appreciably to output. One important reason for this is that full utilization of productive capacity in hand-pounding is constrained both organizationally (various bottlenecks) and seasonally (in practice implements are used one shift a day for about 150 days a year).

In the absence of reliable data, estimates of working-capital requirements were made on the basis of four alternative assumptions relating to costs and time lags. In each case the mechanized techniques gave higher surplus–capital, capital–labour, and output–labour ratios than the hand techniques, and lower capital–value added and capital–output ratios.

See also the entry for D. R. Campbell.

BHALLA, A. S., and GAUDE, J.: 'Appropriate Technologies in Services with Special Reference to Retailing', I.L.O., mimeo, January 1973.

This paper examines special characteristics of technological choice in different types of service activities. The authors argue that the role of organization and of the consumer are often more significant than the conventional factor inputs (capital and labour) as determinants of technological choice. Working capital is also of much greater importance than in the case of manufacturing.

The second part explores economic and technical relationships in retail distribution in Lima, Peru. The main conclusions are:

(*a*) The substitution possibilities between labour and capital are quite small owing to the heterogeneity of inputs in the processes in services.

(*b*) Economies of scale are important in retailing, above average in general merchandise, automobiles, and gasoline, and below average in food and beverages and clothing.

(*c*) For given sizes of shops, variations in productivity are associated with such factors as the ratio of wage–labour to total employment. Labour productivity tends to increase with an increase in this ratio in most retail groups.

BOON, G. K.: *Economic Choice of Human and Physical Factors in Production*, North-Holland, Amsterdam, 1964.

This is one of the most detailed analyses of choice between techniques. Chapters 1–3 explain the methodology of the micro-economic analysis used. Chapters 4–6 present production data for alternative techniques—those generally known and used in the Netherlands in 1956 in the case of the industrial processes, and a cross-section of techniques simultaneously applied in a group of countries at different levels of industrial development in the case of the non-industrial processes. Chapters 7–11 explain how the approach can be extended into a macro-economic analysis.

The industrial techniques analysed are for metal turning, woodworking, and metal-facing; the non-industrial techniques are for grain production, ploughing, and field trenches. In each case it is shown how the optimum technique of production—the method with the lowest total costs of production for a specific output range—changes according to the prices of capital and labour, scale of production, skills, and product quality.

The influence of the prices of capital and labour on the least-cost output range for the industrial operations can be seen from the following:

	Annual capacity output (pieces)		Lot size (pieces)			Machine	Percentages			
							Market prices		Accounting prices	
			A	B	C		Optimal output range	Utilization degree	Optimal output range	Utilization degree
Turning	(*a*)	6,500	4	6	3	General-purpose	0–7	27	0–32	100
	(*b*)	10,218	16	24	12	Single-purpose	7–25	50	32–50	100
	(*c*)	16,718				General + single purpose	—	—	50–60	75
	(*d*)	21,740	104	156	78	Special-purpose	25–100	100	60–100	100
Facing	(*a*)	5,320		5		General-purpose	0–12	32	0–30	100
	(*b*)	6,580		5		Single-purpose I	—	—	30–46	100
	(*c*)	6,450		5		Single-purpose II	—	—	—	—
	(*d*)	14,290		15		Special-purpose	12–100	100	46–100	100
Woodworking	(*a*)	29,000		5		Multi-purpose	0–1	7	0–17	100
	(*b*)	62,500		20		Single-purpose	1–3	8	17–20	50
	(*c*)	63,000		30		Single + special purpose	3–25	66	20–100	100
	(*d*)	170,000		40		Special-purpose	25–100	100	—	—

The Netherlands Economic Institute, Rotterdam, published the author's studies of individual processes separately under the title *Alternative Techniques of Production*:

1. 'A Case Study of Filing and Grinding'—see above, and also the entry for J. Tinbergen.
2. 'A Case Study of Three Turning Operations'—see above, and also the entry for J. Tinbergen.
3. 'Multi-Purpose versus Single-Purpose Woodworking Machinery: Two Case Studies of Furniture Production'—see above, and also G. K. Boon, 'Choice of Industrial Technology: The Case of Woodworking', *Industrialization and Productivity*, Bulletin No. 3 (March 1960), pp. 25–31.
4. 'A Case Study of Wooden Window-Frame Production: Scale of Woodworking Machines'—see above, and also G. K. Boon, 'Choice of Industrial Technology: The Case of Woodworking', *Industrialization and Productivity*, Bulletin No. 3 (March 1960), pp. 25–31.
5. 'A Case Study of a Construction Process: Field Trenches'—see above.
6. 'Choice of Agricultural Technology: Five Methods of Producing Grain'—see above.

BOON, G. K.: 'Choice of Technique: The Case of Metal-Machining', mimeo, El Colegio de Mexico, June 1972.

Investigates the sensitivity of 'machine optimality' (minimum costs at full utilization level of machines) to a number of key variables, including:

(*a*) prices of capital and labour—four price sets;
(*b*) size of lots (production runs)—seven values;
(*c*) price of factory floor space—two prices;
(*d*) price of equipment—two prices;
(*e*) number of shifts—two patterns;
(*f*) efficiency of labour—two rates.

The two most important variables were found to be (*a*) and (*b*) above. In general, the less complex and extreme the characteristics of the product, the more 'machine optimality' depends on lot size since for such a product it is possible to create special machines which are so efficient that only the degree of utilization of these machines determines their optimality; the degree of utilization is determined, principally, by the size of the production runs and the annual volume of the products required. For more complex products the prices of capital and labour remain more important.

CAMPBELL, D. R.: 'Choosing Techniques; An Indian Case: A Comment', in *Oxford Economic Papers*, March 1967, pp. 133–5.

Criticizes some of the procedures used by A. S. Bhalla in his paper on choice of rice-processing techniques (q.v.). The calculations of depreciation are made with respect to total capital rather than to fixed capital, a procedure also used by Bhalla in his analysis of cotton-spinning techniques (q.v.); labour is treated as being homogeneous, although there are wide variations between techniques in both skills and the number of days worked per year; and no shadow accounting procedures are used, for instance to take account of the foreign-exchange contents of the different techniques.

COLES, D. M. S.: *The Vegetable Oil Crushing Industry in East Africa*, Makerere Institute of Social Research, Occasional Paper No. 4, Oxford University Press, 1968.

Describes the different production techniques in use, but does not compare costs or labour-intensities. In the extraction process hydraulic presses, screw presses, and solvent extractors are all used.

DIAZ-ALEJANDRO, C. F.: *Labour Productivity and Other Characteristics of Cement Plants: An International Comparison*, Economic Growth Centre, Yale University, Centre Discussion Paper No. 105, 1972.

On the basis of information obtained by questionnaire the following comparisons between Latin American and some industrialized countries' (Australia, Canada, U.S.A.) cement plants emerged.

In Latin America average labour productivity was one-quarter and wages one-third of those in the industrialized countries. Using power usage and size as proxies for capital, the Latin American plants using between 60 and 64 per cent of the capital produced an output of about 58 per cent of that of the industrialized countries' plants. Hence, if anything, capital–output ratios were slightly higher in Latin America, while

capital–labour ratios were much lower. Together with scale this variation in capital–labour ratios was the most important explanation of the labour productivity differential, implying certain substitution possibilities. Various proxies were used for capital, including horse-power, killowatt hours, and number and size of kilns.

Taking only efficient plants, unit capital costs for the industrialized countries were on average over 50 per cent higher, and labour inputs about 75 per cent lower, than for Latin America. Unit capital requirements in terms of horse-power used first decline and then increase as scale increases for both groups, though there was no clear pattern for labour productivity.

The author concludes that despite certain ambiguities, his data lend support to the hypothesis that substitution possibilities exist in the cement industry. Regressions relating capital–labour ratios to wage rates and capacity support this conclusion.

DOYLE, L. A.: *Inter-Economy Comparisons: A Case Study: A Comparative Study of Industrial Development, Currency Devaluation, and Inflation*, University of California Press, 1965.

Compares capital and running costs of two cement plants using identical machines, both completed and started operating in 1957, one in Indonesia and the other in the U.S.A. The U.S.A. plant was running at about 150 per cent of the capacity of the Indonesian plant.

The Indonesian plant involved more than twice the investment of the American plant, due mainly to investment in infrastructural facilities, including administration and housing, power, an ocean dock, and a bag factory. Investment per ton of cement was $114 in Indonesia, compared with $34·2 in the U.S.A.

The Indonesian plant employed 996 people (368 of whom were non-manual) with total wage costs of $470,000 p.a., while the U.S. plant employed 204 (25 non-manual) with total wage costs of $1,500,000.

DREIBLATT, D.: *The Economics of Heavy Earthmoving*, Praeger, 1972.

The first half of this book discusses technological, operational, and economic factors with reference to a number of well-known projects. The second half presents cost-benefit analyses of two actual projects, based on estimates given by international consultants, and on governmental data in the case of the labour-intensive methods. The first project analysed is an unnamed earth dam, the second is the Rasul—Qadirabad Link Canal in Pakistan.

The author finds the productivity of labour-intensive methods so low by comparison with capital-intensive methods, and hence the costs so much higher, that he concludes that capital-intensive methods should be used at all times. This conclusion, he claims, is reinforced by consideration of the cost of social overheads and of opportunities foregone through delay in completion.

The book contains an extensive bibliography, not all the titles of which are included separately in this present bibliography.

See also entries for: U.N. Department of Economic and Social Affairs, *Industrialization and Productivity*, nos. 1 and 3; I.L.O.: *Men Who Move Mountains*.

Economic Weekly (now *Economic and Political Weekly*), Bombay.

There was a run of articles on the question of choice of technique in 1956 and 1957, mainly with reference to the failure of the modified Gandhi spinning-wheel, the Ambar Charkha, which featured prominently in the Second Five Year Plan. The main empirical articles appeared as follows:

14/10/56 'The Economics of Ambar Charkha', by K. A. Naqvi. Concludes that the charkha investment made by the plan implied an I/O ratio of between 6 and 10 depending on the assumptions made, compared with a ratio for the mill method of about 2. Moreover, the mill method would employ only 25 per cent fewer workers while producing an investible surplus of nearly Rs20 m. compared with no surplus at all from the Ambar Charkha.

6/7/57 'Rationale of the Ambar Charkha', by V. M. Dandekar. Estimates that the Ambar Charkha programme involved a wage subsidy of more than 80 per cent. Moreover, the existing industry was not traditional nor were its employees a high priority for relief—more than 90 per cent of spinners were women from the lower middle classes whose status prevented them from looking for alternative occupations.

19/10/57 'A short Note on the Ambar Charkha', by A. K. Sen. This article was later summarized in an appendix to the author's book *Choice of Techniques* (q.v.).

See also the entry for A. S. Bhalla (1964).

ERLENKOTTER, D., and MANNE, A. S.: 'The Case for Large Fertilizer Plants in India', *Development Digest*, vi: 2 (April 1968), pp. 102–9.

Discusses ways of taking advantage of economies of scale in planning the distribution of plants in India.

But see also the entry for P. Foster and D. Wood.

FOSTER, P., and WOOD, D.: 'The Case for Small Fertilizer Plants in India', *Development Digest*, vi: 2 (April 1968), pp. 110–18.

Explores the advantages of prefabricated 'skid-mounted' plants. These include:

(*a*) a smaller marketing area—large plants, requiring naphtha, must be situated on the coast and hence supply a semicircular area only;
(*b*) less demands on management;
(*c*) the possibility of vesting ownership in a co-operative;
(*d*) much shorter construction time with consequent savings in interest charges and imports of fertilizers and grains.

On various time, capacity, and cost assumptions the author compares the development costs and returns of one large plant and of seven small plants of combined capacity equal to the large plant. Net returns (in millions of rupees) are estimated as:

	Year 1	Year 2	Year 3	Year 4	Year 5	Year 6	Year 7	Year 8
Large plants	−20·1	−60·3	−184·0	−150·4	590·3	674·6	716·8	716·8
Small plants	−249·9	95·6	693·5	693·5	693·5	693·5	693·5	693·5

Thus it would take seventy years for the large plant to overtake the small. Also, the effects on income distribution would be significant, though the authors do not try to calculate these.

See also entry for D. Erlenkotter and A. S. Manne.

GOUVERNEUR, J.: *Productivity and Factor Proportions in Less Developed Countries: The Case of Industrial Firms in the Congo*, Oxford, 1971.

Analyses the nature of long-run changes of techniques, productivity, and factor proportions *within* industrial firms in less developed countries, and considers the question of productivity differentials *between* firms in less developed and advanced countries. Data were gathered for eight Belgian companies set up in the Congo long before World War II. Their activities include the mining and processing of low-grade coal, tin, copper, and tin oxide, the manufacture of sulphuric acid and Portland cement, shipbuilding, and textiles.

'The entrepreneur must compare the economies resulting from the latest technical knowledge embodied in the modern technique to the diseconomies resulting from its suboptimalities with respect to the local conditions.' Among the firms studied, the nature of the raw materials, war scarcities, the peculiarities of the ore bodies mined, and considerations of product quality and uniformity also affected the choices made.

Using a theoretical framework derived from W. E. G. Salter (q.v. p. 47), the author predicts that firms in LDCs will generally record a decline in L/O and a rise in I/L as a result of the combined action of progress, substitution, and scale effects as successive techniques are created in the advanced country. The empirical analysis supports this conclusion, the only cases where the transition was from a modern technique to an old one being those where L/O rose and I/L declined. The author argues that changes in the rate of capacity used and in the number of shifts worked were not significant in the sample studied, but that reductions in the labour force modified the changes in L/O and I/L.

Long-run changes in I/O cannot be inferred *a priori* from deductive analysis since the progress and substitution effects pull in opposite directions, while the influence of the scale effect depends on the phase of returns. During the post-war period I/O increased for the two big mining companies and declined for the small mining company and for the five manufacturing companies. A clear tendency was established towards a long-run convergence of L/O between the Congo and Belgium, and, to a lesser extent, of I/O and I/L.

Chapter IX tests the Hirschman hypothesis (see Diaz-Alejandro (1965) and Healey) on productivity differentials between different types of industry and activity between developed and developing countries by comparing two plants in two industries, shipbuilding (product-centred and man-paced) and flour milling (process- and machine-paced). He finds that the labour productivity differential was significantly greater for flour-milling than for shipbuilding. Splitting up the productive process shows that productivity differences between the Congo and Belgium are least for those directly working on the central machine-paced process (5 per cent), and much greater for general handling activities (116 per cent). Hence he concludes the central processes of an industry do not set the pace of all operations, as, he claims, Hirschman implicitly asserts. (Chapter IX appeared originally in *The Bulletin of the Oxford University Institute of Economics and Statistics*, vol. 22, no. 3, August 1970.)

GOVERNMENT OF INDIA, Appropriate Technology Cell, Second National Seminar on Appropriate Technology, July 1973.

(i) K. L. Nanjappa, 'Need Based Technology in Small Scale Industries', quotes examples of improvements in technology as a result of local research and development in the small-scale industries of ceramics, leather, and engineering.

(ii) A. K. N. Reddy, 'Choice of Alternative Technologies, Vital Task in Science and Technology Planning', cites an example of choice of technology in production of dry cells, arguing that small-scale units are as efficient as large-scale and involve substantially more employment. Unit costs are only slightly higher in small-scale units.

(iii) 'Appropriate Technology in Road Construction' describes research undertaken in India, and how appropriate methods for different parts of road construction differ in developing and developed countries.

(iv) Report of Working Group on appropriate methods in Building Construction similarly describes research and development results.

(v) Report of the Sub-Group on Scaling Down of Cement Plants gives details of the comparative costs of four experimental small-scale cement plants. Also cost comparisons of plants of different sizes. Unit costs decline with scale, particularly fuel. Staff salaries (per ton) substantially greater for very small units (2 tons per day) but little difference between medium (30 tons) and larger-scale units (100 tons).

GRANICK, D.: *Soviet Metal-Fabricating and Economic Development*, University of Wisconsin Press, 1967.

This is a study of Soviet industrial policy since the Revolution, focusing on the implications of the decision of the late 1920s to invest in heavy industry. Chapters 5 and 6 particularly are relevant to the question of choice of technique.

Chapter 5 (pp. 167–70) argues that vertical integration was implicit in the system of physical planning, the necessity of choosing one or another key success indicator, the insistence on full utilization of the capacity of capital-intensive industries, and in the belief that results should be achieved quickly—and argues that it was responsible for a major distortion of resource use.

Chapter 6 argues that Soviet high-priority industry consistently substituted labour for capital within the bounds of the technology known to the relevant management at the time, whether consciously or not, and that this is the opposite of what one would have predicted *either* on the basis of Soviet theory *or* on the basis of least-cost calculations. This is not, however, to say that the capital–output ratio was always minimized as in many cases capital was used as a substitute for organizational reform.

On a comparative basis with American experience, auxiliary operations and maintenance were very labour-intensive. In assembly operations 77 per cent of manual workers worked by hand, even though power wrenches were believed to double labour productivity; likewise, the widespread use of casting increased the use of non-turret lathes which are wasteful of labour. The author argues that the decision to operate the inspection function labour-intensively led to a waste of resources. The

major exception to the hypothesis was the importing of new equipment during the first Five Year Plan so as to economize on skilled labour.

The author notes that a plan based on the Galenson–Leibenstein hypothesis would have meant sacrificing some intangible investment in labour training, and also some of the planners' socio-political welfare aims.

INTERMEDIATE TECHNOLOGY DEVELOPMENT GROUP: *Report on the Development of Cottage Industries based on Sisal, Wood- and Metal-Working and Leather in Kenya*, Maxwell Stamp, September 1969.

Emphasizes the need for deliberate policies to modify the free play of market forces which favour large, capital-intensive metropolitan projects. While manufacturing activities related to food, clothing, shelter, basic infrastructure needs, and the first-stage processing of raw materials do not require sophisticated technologies, they nevertheless require technologies which are currently unknown or unfamiliar. If these are to be encouraged, appropriate technical and commercial know-how, funds, and supporting programmes to meet other aspects of the rural economy must be provided, and local initiative fostered. This is necessary if farming is to become prosperous, both to provide inputs such as buildings, cattlefeed, and simple equipment and to provide an outlet for such consumer requirements as better furniture and household commodities.

Contains detailed recommendations for these industries.

INTERNATIONAL BANK FOR RECONSTRUCTION AND DEVELOPMENT, International Development Association: *Study of the Substitution of Labour for Equipment in Road Construction*. Phase I: Final Report, October 1971, mimeo.

This detailed study begins by examining many alternative methods to determine the economically efficient method (or combination of methods) to build a given road of specified quality. It next considers the increase in economic costs that would be required to employ successively more and more labour to the point of displacing virtually all equipment for the sake of job creation.

The authors discovered that the only way to obtain reliable information sufficiently detailed to permit study of the substitution problem was through direct field observations; they developed a disaggregation into 109 basic construction activities, in seventy of which substitution possibilities exist. Several hypothetical engineering analyses of road projects are presented, based on estimates by two firms of consultants, to illustrate the problems and effects of substitution. They are based on assumed rates of equipment and labour costs, and on productivity data from several different sources. Certain environmental factors and engineering and organizational problems associated with labour substitution are not included in the analyses but are discussed separately.

The major conclusions of the study are:

1. It is technically feasible to substitute labour for equipment for all but 10–20 per cent of total road construction costs, and for all but 2–15 per cent of costs if an intermediate quality is acceptable.
2. The economic feasibility of labour substitution will depend,

among other things, on the productivity rates of equipment and labour and the wage for unskilled labour.

3. Intermediate technologies involving a mixture of modern equipment and manual methods appear promising and should be further investigated.

4. While employment in road construction could be greatly expanded, the additional employment created would constitute only a fraction of that likely to be needed in the foreseeable future. In the case of Morocco it is estimated that maximum labour absorption in road construction could provide at most 3 per cent of the jobs necessary to maintain the current unemployment rate over the next seven years.

Following this study, the IBRD Economics Department initiated a computer model to permit removing a number of restrictive assumptions which were employed in the Phase I analyses so as further to define the data to be collected in the Phase II studies, scheduled to start in India in November, 1971.

The study contains very full bibliographies of the engineering and economic literature on road construction. Most of the items have not been listed separately in this present bibliography.

INTERNATIONAL LABOUR OFFICE: *Men Who Move Mountains*, Bombay; I.L.O., 1963.

Contains output and cost data on traditional Indian methods of manual earth-moving, and makes comparisons with other Asian countries. See also the following publications:

UN(ECAFE): *Manual Labour and Its More Effective Use in Competition with Machines in the ECAFE Region*, E/CN. 11/WRD/Con.3/L.1.

S. Taniguchi: *Civil Engineering Construction*, Kazama Publishing Co., Tokyo.

UN(ECAFE): *Report of Working Party on Earthmoving Operations*, U.N. Publication 61.II.F.4.

INTERNATIONAL LABOUR OFFICE: *Progressive Industrial Technology for Developing Countries*, UNIDO: ID/CONF.1/B.17, Vienna, 1967.

Contains examples of bad (employment) results from transplanting advanced industrial technology to conditions for which it was not designed. The industries involved were ceramics, plastic shoes, and tanning. Also, two examples of the successful use of modern technologies, the one to manufacture sewing machines where they had previously been imported, the other a fibre-board plant.

INTERNATIONAL LABOUR OFFICE: *Matching Employment Opportunities and Expectations: A Programme of Action for Ceylon . . .*, Geneva, 1971, Report chapter 5, pp. 69–83, 105, 186.

Estimates (p. 105) capital, output, and employment in Ceylon in public, private large- and small-scale activities; compares the ratios of alternative techniques in weaving (p. 186) (see B. Hewavitharana) and discusses areas in which Ceylon might be able to develop more labour-intensive technologies. Data on production costs and employment in the

manufacture of different grades of New Process Rubber (p. 76) indicate the scope for variations in processes. Quotes evidence of technical assistance and labour problems adversely affecting the choice of technique, and suggests the setting up of industrial research institutes and a light machine-goods sector.

The report argues that the range of technical choice is widest in construction, transport, and services where the output consists of non-tradables and hence quality and time are less crucial. In construction the main constraint is the need to synchronize work with monsoons and the agricultural seasons. The report quotes (p. 79) an estimate which claims that a certain road could have been completed in the same time at less than one-third of the cost using 136 men instead of 14 men and 6 machines. The report comments that this is probably an exaggeration, if only because wheelbarrows and other light equipment would undoubtedly be required.

It is argued that there are over-capital-intensive techniques in use in transport (especially in the case of automatic lifts and conveyor belts for materials handling) and in banking; and potentially in other services—supermarkets, calculating machines, power laundries, and household mechanical appliances.

INTERNATIONAL LABOUR OFFICE: *Automation in Developing Countries*, Geneva, 1972.

In addition to a round-table discussion on problems associated with the introduction of automation and advanced technology in LDCs, there are six case studies of organizations introducing advanced technology. These are: computerization in the Banco do Brasil; the mass production of cakes in Colombia; the introduction of electronic data processing in an Indian textile firm, and also by Ethiopian Airlines; computerization in two Bangladesh banks; and the automation of tin-can production in Tanzania.

In each instance the new technology contributed to higher profits by slowing down employment growth, and in the case of the Indian textile firm and the Colombia bakery quality and output were also improved significantly. However, in each case the new technology was only marginally superior to alternative methods. The authors suggest that much of the explanation of the easy and ready introduction of labour-saving equipment lies in the fact that where the wage bill is a small percentage of total costs a few extra workers can easily be carried until attrition or output expansion re-establish a desired ratio.

INTERNATIONAL LABOUR OFFICE: *Roads and Redistribution, A Social Cost-Benefit Study of Labour-intensive Road Construction Methods in Iran*, World Employment Programme, Geneva, 1973.

Case study of one highway, two feeder roads, and two rural roads. Finds that adoption of more labour-intensive methods is socially feasible for each of the roads examined; equipment use could be reduced and employment significantly increased. Adoption of more labour-intensive techniques is uneconomic from the point of view of the private entrepreneur. Whether or not it is socially desirable depends on the priorities the Government attaches to maintaining a high rate of future income, as

against reducing present inequalities, particularly as between the urban and rural sectors.

It is estimated that for the highway programme 32,500 man-year employment equivalents could be created (or 10 per cent of forecast open unemployment); the extra cost would be 22 per cent of the cost of the programme. For secondary roads, 16,500 man-years of employment could be created at an additional cost of 30 per cent of the programme.

INTERNATIONAL LABOUR OFFICE: *Men or Machines: A Philippine Case Study of Labour-Capital Substitution in Road Construction*, I.L.O. World Employment Programme, Geneva, forthcoming.

JOHNSON, W. A.: *The Steel Industry of India*, Harvard University Press, 1966.

Chapter 3 considers the question of factor endowments and resource allocation. Argues that relative abundance of raw materials is relevant to choice of industry as well as capital and labour, and this may justify the introduction of capital-intensive industry like steel in India. Argues that 'in the steel industry technology is relatively inflexible and the substitutability of labour for other inputs, notably machinery, is limited'. In India with few exceptions new mills have been equipped with the latest machinery. Older more labour-intensive methods (e.g. hand hot mills in rolling of sheets instead of semicontinuous and continuous strip mills) are less efficient with less output per rupee investment. Later methods also produce better-quality product. Mechanized methods of transporting semi-finished products allow subsequent processing with less reheating and thus economize on fuel and reheating capacity. There are opportunities for labour-intensive operation outside the immediate operations of steel mills—in mining ore, and in the handling of raw materials and finished products.

JUDET, P.: 'Minisidérurgies et Réduction Directe', mimeo, Institut de Recherche et de Planification, Grenoble, 1970.

Gives cost estimates for small-scale semi-integrated steel plants with capacities as low as 50,000 tons per year.

KHADI AND VILLAGE INDUSTRIES COMMISSION: *Khadi and Village Industries: A Perspective*, Bombay-56, 1972.

Outlines the Commission's work in helping to improve productivity and organization in village industries in India. Makes the following estimates of the investible resources required to employ one person in various industries in India:

Steel	Rs160,000
Heavy machine building	Rs100,000
Heavy electricals	Rs 50,000
Fertilizers	Rs 40,000
Small-scale industries	Rs 5,000
Handicrafts	Rs 1,500
Khadi and village industries	Rs 1,000

Appendix II lists the improvements in technology made by the Commission.

A handbook, *Patterns of Assistance for Khadi and Village Industries*, sets out the subsidies available for each industry.

A series of thirteen articles, one on each of the industries covered by the Khadi Commission, appeared in the Bombay weekly *Commerce* between 23 September 1972 and 31 March 1973.

KILBY, P.: *African Enterprise: The Nigerian Bread Industry*, Stanford, 1965.

Chapter 4 describes the baking process in use in Nigeria and aspects of technology. Beyond a certain point (600 lb. per batch) economies of scale are not significant, the constraints stemming from the biological process of fermentation and the technology of the dough brake.

Data on capital–output and labour–output ratios are given for six firms out of a total sample of fifty-nine as representing different sizes, market orientation, and technologies. In particular, the firm producing the 'economy' loaf economizes on capital but has high total costs because of the high raw-material content; the technically most advanced firm which produces a 'luxury' loaf minimizes losses in the production process but has trouble with spare parts, power failures, high fuel costs, and finding skilled supervisors—and the limited market for 'luxury' loaves means it operates below capacity; another firm substitutes organization and superintendence for capital; another firm, with a 'distribution' orientation, has more than half its capital in delivery vans.

Chapter 5 compares productivity and costs of five firms; efficiency of raw material conversion; and output–labour and output–fixed capital ratios.

KILBY, P.: *Industrialization in an Open Economy: Nigeria 1945–66*, Cambridge, 1969, especially chapters 4–5.

Emphasizes the far wider spectrum of product differentiation to be found in LDCs than in developed countries. 'Even in the case of so seemingly homogeneous a product as bread, four distinct sub-markets were identified.'

Chapter 4 contains observations on capital-intensity in some import-substituting industries. In cigarette manufacturing the most automated production techniques available have been adopted. Within Nigeria's well-protected market the objective has been to maximize sales, subject to the constraint of a satisfactory rate of return; automated techniques have made it possible to expand output and capacity rapidly, to provide a full range of brands or price lines, and to have ensured uninterrupted supply. Greater use of old machines and labour-intensive handling techniques would reduce both capital costs and the number of senior (expatriate) technicians; on the other hand, such a choice would involve higher operative skills, greater reliance on Nigerian supervisors, and greater vulnerability to interruptions as a result of human failure. A further crucial factor is that in the case of cigarettes (and also beer) the cost of manufacturing is less than 10 per cent of the ex-factory price, the rest being made up of expenditures on raw materials, advertising, selling, profit, and, above all, taxes. The factors influencing choice of

technology in brewing and bottling are the same as for cigarettes. In cement a more capital-intensive 'dry-process' which reduces the fuel requirement by a third has been adopted to get round the problem of transporting large quantities of coal.

Chapter 5 discusses processing for export and contains a discussion of palm-oil extraction. There were four methods in use in 1963, and table 44 summarizes the main operational characteristics of each. On the basis of simple extraction efficiency—the criterion which has largely guided government policy—each new method should have displaced its predecessor. In fact the more labour-intensive methods have in general proved economically more efficient. The four methods are: hand method, screw-press, Pioneer Mill, and hydraulic hand-press.

MASON, R. H.: 'The Relative Factor Proportions in Manufacturing: A Pilot Study Comparing U.S. Owned Subsidiaries and Local Counterparts in the Philippines', prepared for U.S.A.I.D., mimeo, 1969.

In a sample of 130 firms, the 46 U.S. firms had assets per employee of $11,370, compared with $9,583 for the 84 local firms. The discrepancy was due to non-participation by U.S. firms in textiles and tobacco. When these were excluded the figure for the local firms rose to $11,419.

In a comparison of eighteen paired firms, the U.S. firms tended to be more capital-intensive, though since they also paid higher wages their factor proportions (when measured by the *wage bill*) were comparable. The U.S. firms employed a larger proportion of both executive and low-skilled employees. Only four of the firms indicated that skill shortages were so severe as to force them to alter plant design as compared with the design they would have preferred. All the U.S. firms used equipment of U.S. origin, whereas the Filipino firms got 70 per cent from Europe and 30 per cent from the U.S.A.

Half of the firms in the larger sample said that they would use the same equipment again, while most of the others said that changes would be neutral between capital and labour. Six Filipino firms said that innovations would be labour-saving in order to improve quality.

Most firms were of the opinion that plants in the Philippines were entirely different from plants in the U.S.A. which produce similar products, since their machines had to have smaller capacities, tend to be designed for small-batch operation rather than continuous production, and are less specialized.

Examples were given of processes where the most modern technology was more capital-saving than the previous one, for instance where a process previously necessary could be dispensed with.

MILLER, W. L.: *An Economic Analysis of Oil Palm Fruit Processing in Eastern Nigeria*, Ph.D. thesis, Michigan State University, 1965, published on demand by University Microfilms Ltd., High Wycombe, England, and Ann Arbor, Michigan, U.S.A.; bibliography.

The technologies investigated are as follows: for collecting the fruit, headload, bicycle, and lorry: for processing, hand press, screw press, hydraulic hand press, 'Pioneer' oil mill, and Stork major mill. At least 80 per cent of the oil exported and 90 per cent of the total palm-oil

produced in Eastern Nigeria comes from the small-scale hand and screw presses.

Of the collection technologies, for all quantities at present required by each sort of processing plant, the headload method (using female labour) was the cheapest. Using male labour the bicycle method would be the cheapest at all levels, the lorry method only becoming economic at very high levels.

The following table compares efficiency indices for the various technologies, efficiency being computed as 100 × average revenue ÷ average total cost:

	Average season for each technology	150-day season for all technologies
Okigwi hand method	71	73
Abak hand method	95	96
Average hand method	83	84
Abak screw press	95	97
Okigwi screw press	89	89
Average screw press	92	93
Hydraulic hand press	94	94
'Pioneer' oil mill	95	90
Stork major mill	87	71

Variations in fruit price and wage rates do not affect the stability of the conclusion that the screw press, hydraulic hand press, and 'Pioneer' oil mill have similar levels of efficiency. As the size of plant increases, less fruit and labour are required to produce a hundredweight of oil. Also as plant size increases the average variable cost component of average total cost declines in relative magnitude while the average fixed cost component increases.

Technical efficiency in the industry is maximized by the screw press, the hydraulic hand press, and the 'Pioneer' oil mill. Use of the hand method maximizes employment and minimizes the value of capital imports. Use of the Stork mill maximizes the oil yield for export and the *per capita* incomes of the employees. Changing the processing method for the export market from the screw press to either the hydraulic hand press or the 'Pioneer' oil mill does not benefit the economy because the advantages of higher oil exports are balanced by capital imports.

MÜLLER, J.: 'Labour-Intensive Methods in Low-Cost Road Construction: A Case Study', *International Labour Review*, vol. 101 (January–June 1970), pp. 359–75.

Report of a resident engineer on a project in a remote region of subtropical Africa which started out as a highly mechanized project but had to resort to increasingly labour-intensive methods. The higher indirect operational costs of the capital-intensive method and the associated economic cost of delays in opening the road narrowed its cost advantage over the most labour-intensive method. Suggests that if shadow prices were used and the social benefits of employment considered, the labour-intensive method would have been best. Advocates a mixed strategy, using more mechanized techniques for certain processes.

MÜLLER, J.: *Choice of Technology in Underdeveloped Countries, exemplified by Road Construction in East Africa*, The Technical University of Denmark, 1973.

Contains theoretical discussion of the meaning of appropriate technology and methodological procedures for choosing technology—particularly the use of a multi-objective decision model combined with adaptation to local conditions. The theoretical model is illustrated by some detailed empirical data on roads in East Africa.

NAYUDAMMA, Y.: *Wet Blue Chrome Leather for Export*, UNIDO: ID/WG.79/3, Vienna, 1971.

A comprehensive technical discussion of the subject by the Director of the Central Leather Research Institute, Madras. Contains a discussion (pp. 133–8) of the possibilities of improving the technologies used by cottage and small-scale tanners so as to raise the quality of their products to export standards, and also the organizational problems involved. 'It is suggested that serious attention should be paid to this problem [of reorienting the cottage and small-scale sector], as the existing reportedly uneconomic units could be switched on to a more profitable line of activity.'

NETHERLANDS ECONOMIC INSTITUTE: 'The Economics of Mill Versus Handloom Weaving in India: A Progress Report on a Method', Publication No. 7/56, Rotterdam, 1956.

Outlines a method for evaluating the 'total' economic characteristics of the two sectors, and presents some data relating to them. No calculations are made, however, as the information 'appeared both too inaccurate and incomplete'.

PICKETT, J., FORSYTH, D. J. C., and MCBAIN, N. S.: 'The Choice of Technology, Economic Efficiency and Employment in Developing Countries', *World Development*, vol. 2, no. 3, March 1974.

This is an inquiry into the choice of technology in the sugar and footwear industries in Ethiopia and Ghana. It involved the identification of as wide a range of alternative techniques as possible in each industry, and the costing of the use of each alternative for given levels of output in Ethiopian and Ghanaian conditions.

Three basic systems of sugar production were examined: (*a*) the vacuum-pan process; (*b*) the Jaggery/vacuum-pan process; and (*c*) the Khandsari type open-pan sulphitation process. Within each system variants of sub-processes are available. In footwear there is basically one system, but a large number of alternatives for each operation.

For the sugar comparisons a Ghanaian vacuum-pan factory with an operating capacity of 24,000 tons p.a. (assumed to be fully utilized at all times) was investigated. The net present value and the internal rate of return were calculated, given the initial fixed capital investment and taking the most efficient manning system and the most efficient flow of current inputs. The calculations were repeated for the same annual

output and time period for the Khandsari process as if it were in use in Ghanaian conditions. Adjustments were made to both sets of calculations to obtain a measure of 'social profitability'. The Khandsari process would have required a capital investment of one-third of that required by the actual factory and would have employed 700 full-time and 3,000 seasonal workers as compared with 476 full-time and 219 seasonal workers required by the actual factory; it would also have been more profitable.

To make comparisons for the shoe industry, three 'synthetic' factories were analysed in which the production process was an amalgam of known operations conventionally used in the U.K. and Africa. Each factory was to produce 300,000 pairs of shoes p.a., be efficiently run with one shift, use imported synthetic sole units, operate over a period of twenty-five years, and use locally produced leather in Ethiopia and imported leather in Ghana. 'As with the sugar comparisons, the most profitable shoe factory would also use less capital and employ more labour than the relevant alternatives in Ethiopia and Ghana. Thus, the initial capital investment in factories A, B, and C respectively would be ₵693,000, ₵350,000, and ₵276,000 in Ghana, and Eth. $1,043,000, Eth. $686,000, and Eth. $512,000 in Ethiopia. The choice of factory C rather than factory A would increase total and unskilled labour employment by 28 per cent and 37 per cent respectively in both countries.'

PRASAD, K.: *Technological Choice Under Developmental Planning*, Popular Prakashan, Bombay, 1963.

A detailed analysis of the position of the cottage industries—cotton spinning and weaving, rice processing, vegetable oil, gur-khandsari, leather tanning, leather footwear, paper, match, and soap—in the Indian economy, with special reference to the Second Five Year Plan.

Analysis of the cost structures shows that for each industry except tanning, footwear, and paper, working capital is considerably more important than fixed capital, in each case representing more than 70 per cent of total capital. In all cases except handspinning (where labour costs are most important), raw-material cost is the most important element of production costs, mostly accounting for something in the range 60–90 per cent of total costs.

To secure the output targets of the Plan less investment would be required for the mill techniques in the case of vegetable oil, tanning, paper, and matches, while in each case the hand techniques would maximize employment in the short run. Taking into account expenditure on social overheads, total expenditure under the Plan would be greater if all investment were in hand techniques rather than mill techniques in all cases except rice, weaving, and leather footwear, though the situation might be reversed for tanning, paper, and matches if a high priority were given to saving foreign exchange. One should also consider the enormous costs of reorganizing, administering, and subsidizing the cottage industries. Considerations of utilizing excess capacity would tend to favour the hand techniques.

On various wage and savings assumptions, assuming that all distributed profits are available for reinvestment and allowing for depreciation, aggregate saving under hand techniques could be higher than under mill techniques in the case of one of four rice techniques, one of two vegetable oil techniques, three out of four weaving techniques, and for

leather footwear and soap. However, the network necessary to mobilize the scattered savings of the hand techniques would be very expensive, though it would have beneficial implications for development in itself.

Finally, the author estimates the length of time required for the mill sector to overtake the hand sector on alternative assumptions of savings in each sector for the various techniques. The estimates for output and employment are within the following ranges:

	Output (years)	Employment (years)
Rice	9–23; never	16–33
Vegetable oil	10–20; never	21–27
Spinning	21–88	54–66
Tanning	0; never	22
Weaving	25–125; never	28–75
Leather footwear	22–110; never	32
Paper	7	19–30
Match	12–17	24
Soap	11–26	15–16

These estimates illustrate the difficulty of planning with uncertain data and the importance of time preference.

RAJ, K. N.: 'Employment and Unemployment in the Indian Economy: Problems of Classification, Measurement and Policy', *Economic Development and Cultural Change*, April 1959, pp. 258–78.

Analyses the performance of the five main cotton-weaving techniques in use in India at the time. The main conclusions are: that although the fly-shuttle hand loom maximizes the output coefficient it could only be sustained by subsidy for all wage rates greater than Rs1·5 per day; that the 'Banaras' semi-automatic hand loom has a slightly lower output coefficient but could generate a profit of 450 per cent even at a wage rate of Rs2 per day; that the cottage power loom both has the lowest output coefficient and generates a small surplus; that the factory non-automatic power loom would maximize the rate of profit for the wage rate range Rs5–13 per day; while the factory automatic power loom would maximize profits for wage rates greater than Rs13 per day.

See also the entry for A. K. Sen, *Choice of Techniques*.

SEN, A. K.: *Choice of Techniques*, 3rd edition, Blackwell, Oxford, 1968.

The main body of this book is a classic statement of one theoretical approach to the question of choice of technique, incorporating different objectives.

Appendix C considers five alternative cotton-weaving techniques for India, drawing on the analysis of Raj (q.v.) among others. On the assumption of the same wage rate for each technique Sen's conclusions are much the same as those of Raj.

Sen also considers the effect of differential wage rates. According to his estimates of wage rates, the 'Banaras' semi-automatic hand loom gives the highest potential rate of surplus. It also gives the highest *actual*

rate of surplus for all propensities to save greater than 0·15. However, allowance for working capital can alter the analysis considerably in favour of the power looms.

The foreign-exchange factor and the time paths of the different techniques in terms of output maximization are also considered.

Appendix D summarizes Sen's analysis of the performance of the modified Gandhi spinning-wheel, the Ambar Charkha, much favoured in the Second Plan, which appeared in the *Economic Weekly*, 19 October 1957 (q.v.). The main conclusion is that the Ambar Charkha would generate a surplus of MINUS 276 per cent.

See also the entry for A. S. Bhalla (1964).

SIET INSTITUTE, Hyderabad: *Appropriate Technologies for Indian Industry*, 1964.

Contains two case studies. The first compares a hand-operated and a power-driven technique for manufacturing a cycle gear-case. At the level of production examined (3,000 cases per month) the hand method is slightly cheaper to produce, has far lower capital–labour and capital–output ratios, and hence generates a much larger surplus.

The second study is of four techniques for manufacturing a hand-operated Japanese-style paddy weeder, an existing handicraft technique and an existing power technique, and an improved version of each. In each case the capital–labour ratio is higher for the improved models (50 per cent higher for the hand technique, 3 per cent for the power technique), and the capital–output ratio lower (17 per cent lower for the hand technique, 45 per cent for the power technique). Again, the improved versions have lower unit costs, the hand techniques slightly lower in each case than the power techniques; above 2,000 units a month the improved power technique would have a very slight cost advantage. The existing hand technique would produce a product of less uniform quality, while both improved techniques would require highly skilled managers.

SOBERMAN, R. N.: *Transport Technology for Developing Regimes: A Study of Road Transportation in Venezuela*, M.I.T., 1966.

STEWART, F. J.: 'Employment and the Choice of Technique: Two Case Studies in Kenya', in *Essays on Employment in Kenya*, ed. D. P. Ghai and M. Godfrey, East African Literature Bureau, 1974.

The two activities studied are concrete block-making and maize-grinding. Five techniques for the former are compared, viz.: hand-operated block-makers, small stationary vibrating machines, large stationary vibrating machines (imported), small laying machines (imported), and large laying machines (also imported); and four techniques for the latter: hand-mills, water-mills, hammer-mills, and roller-mills (imported). The data were collected through personal interviews with managers and/or owners. Twenty-three block-making entrepreneurs were interviewed, using forty different machines, and 103 maize-grinding techniques were investigated.

The main conclusions of the two studies 'suggest that the formal analysis generally used to discuss choice of technique fails to incorporate important aspects of choice'. Firstly, variations in product characteristics

were found to be the key determinant in maize-grinding; they also ruled out the hand block-making technique for multistorey buildings. In maize-grinding the small-scale 'intermediate' technique—the hammer mill—was associated with greater employment output and investible surplus than the more capital-intensive roller mills. These, however, were increasingly popular because the product, though more expensive and nutritionally inferior, was widely preferred. Secondly, the scale of output was found to be an important influence on technical choice: in cement-block manufacture the more labour-intensive techniques were found to be more efficient at low scale of output, but not at high. Thirdly, the level of capacity utilization was of key importance in determining the relative costs of different techniques. The studies revealed systematic differences in wage rates, according to location of production and according to technique. Calculations of surplus generated which assume the same wage rate for each technique are thus misleading.

THOMAS, J. W.: 'The Choice of Technology for Irrigation Tube Wells in East Pakistan: An Analysis of a Development Policy Decision', in D. Morawetz, J. Thomas, C. P. Timmer, and L. Wells, *Studies of Inappropriate Technologies for Development*, Harvard University Center for International Affairs, 1974.

Shows that medium-cost tubewells (powerdrilled, high-speed diesel engine) were selected rather than low social-cost alternatives (labour drilled, low-speed engine) because of the organizational requirements of the implementing agencies, including aid donors. Modern technology was more risky for the former but less risky for the donor agency.

TIMMER, C. P.: 'Choice of Technique in Indonesia', Discussion Paper 72–4, Food Research Institute, Stanford, California, 1972.

Traces the history of recommendations for bulk storage and processing facilities for rice in Indonesia made by a firm of international consultants. Four different types of facilities were considered. Three-quarters of the proposed $65·4 million investment was allocated to two types of equipment, one of which would only be optimal under artificially high paddy prices, the other would never be optimal. Less than one-twelfth of the funds was allocated to the technique which according to the author's calculations would be most 'appropriate' in Indonesian conditions—husker/polisher mills and flat warehouses.

TINBERGEN, J.: 'Choice of Technology in Industrial Planning', *Industrialization and Productivity*, Bulletin no. 1 (April 1958), pp. 24–34.

Suggests a methodology for estimating least-cost techniques based on wage- and interest-rate differentials. Presents cost data on six methods of loading delivery trucks in the U.S.A., four of which are neo-classically inefficient. Also summarizes the results of two studies on filing and grinding and turning by G. K. Boon (q.v.).

UNITED NATIONS DEPARTMENT OF ECONOMIC AND SOCIAL AFFAIRS: 'Capital Intensity in Heavy Engineering Construction', *Industrialization and Productivity*, Bulletin no. 1 (1958), pp. 35–48.

Studies the operations involved in earth moving—excavation, hauling, filling, and compacting—with reference to data for the U.S.A. and Sweden, and extrapolates for the conditions prevailing in LDCs. The factors affecting choice of technique will include: direct production costs, topographical conditions, considerations of economic and social policy (e.g. extent of seasonal unemployment), social overheads, and the time horizon.

Concludes that the use of highly mechanized techniques in LDCs is likely to result in unit costs of operation which are substantially higher than in developed countries for similar levels of mechanization, but on account of considerations of factor *productivity* rather than of factor prices. Poor utilization of equipment both on the job (perhaps little more than 50 per cent of the U.S. level) and over its lifetime, inadequate maintenance, scarcity of skilled labour, and inadequate general facilities such as supply of parts will all be crucial; the effect of low wages will be almost cancelled by the low productivity of labour, while higher LDC shadow interest rates might only raise total costs by some 5–10 per cent.

See also entries for: U.N. Department of Economic and Social Affairs, in *Industrialization and Productivity*, no. 3; D. Dreiblatt, *The Economics of Heavy Earthmoving*; I.L.O., *Men Who Move Mountains*.

UNITED NATIONS DEPARTMENT OF ECONOMIC AND SOCIAL AFFAIRS: 'Capital Intensity and Costs in Earth-Moving Operations', *Industrialization and Productivity*, Bulletin no. 3 (1960), pp. 7–22.

Compares data for standard methods used in Austria, Finland, France, Sweden, U.S.S.R., U.S.A., India, and Poland. Capital is measured by the value of effective physical depreciation of equipment; labour is measured in hours of direct labour used on the job, excluding supervisory and overhead staff. Various assumptions are made about wages, raw materials, and exchange rates.

For the first six countries listed above the capital–labour ratio for excavation work varied between U.S. $0·8 per man-hour and U.S. $1·2 per man-hour; costs per cubic metre varied between U.S. $0·22 and U.S. $0·47. Indian and Polish capital–labour ratios were U.S. $0·3 per man-hour and U.S. $0·05 per man-hour respectively, the low figure for Poland being attributable to the use of unskilled labour to build a rail-track; however, costs per cubic metre were comparable to those of the more developed countries. Analysis of the Indian data gives the following breakdown of costs for a combined operation of excavation, transport, and compaction:

Depreciation	41·4
Lubricants, fuel, etc.	21·8
Repair and spare parts	17·7
Labour: Operating	4·7
Repair	14·4
	100·0

See also entries for: U.N. Department of Economic and Social Affairs, in *Industrialization and Productivity*, no. 1; D. Dreiblatt, *The Economics of Heavy Earthmoving*; I.L.O., *Men Who Move Mountains*.

UNITED NATIONS, Economic Commission for Latin America: *Choice of Technologies in the Latin American Textile Industry*, 1966.

Compares paradigms of three vintages of mill—1950, 1960, and 1965—each containing both a spinning and a weaving section, producing only one specified type of fabric, and each operating with the minimum of idle capacity. Technological developments in the industry in Latin America have concentrated on minimizing the labour force through automatization. Thus the proportion of variable costs (manpower and raw materials) in total production costs declines with each successive vintage.

The main findings of the study are: there is scarcely any saving in costs by choosing the 1950 vintage rather than the 1960 vintage, but there is a sizeable saving in choosing the 1960 vintage rather than the 1965 vintage; labour requirements fall with each successive vintage—1950 = 100, 1960 = 59, 1965 = 44—while capital costs increase—1950 = 100, 1960 = 117, 1965 = 128; whereas an increase in capital costs of 16 per cent would make the 1965 vintage unable to compete, and the 1950 vintage may quickly become commercially uncompetitive, the 1960 vintage would remain viable with an increase in labour costs of up to 70 per cent and of capital costs of up to 12 per cent; the surpluses per unit of output are of the order of 1950 = 100, 1960 = 119, and 1965 = 126.

The study concludes that with low availability of capital, maximum benefits in terms of total investment, the reinvestible surplus, employment creation, and return on capital are attained by use of the 1960 vintage.

UNITED NATIONS INDUSTRIAL DEVELOPMENT ORGANIZATION: *Technological and Economic Aspects of Establishing Textile Industries in Developing Countries*, UNIDO, Vienna, 1967, ID/7, pp. 123–76.

Compares alternative spinning systems of varying degrees of automation:

For a plant of 25,344 spindles producing 250,000 kg. of yarn of 24's count monthly an up-to-date non-automated mill requires 1·77 workers per 1,000 spindles shift whereas a Saco-Lowell semi-automated mill—where the processes of opening, picking, carding, and first drawing are continuous—requires 1·20 workers. Spindles for the non-automated mill cost about $80, for the semi-automated mill about $100. A still more automated system, the Whitin 'systemated' mill, requires only 0·97 workers per 1,000 spindles shift, spindles costing $120 each.

There are also comparisons of six German plants built by Ingolstadt, and a description of an automated system built by Platt Brothers Ltd., U.K. Four types of winding equipment, four types of weaving equipment, and two finishing processes are compared.

Although these are not complete case studies, they could be very useful to anyone attempting such a study. There is a good technical bibliography on pp. 175–6.

UNITED NATIONS INDUSTRIAL DEVELOPMENT ORGANIZATION: *Profiles of Manufacturing Establishments*, UNIDO, New York, 1967, 1968, and 1971 (3 vols.), Industrial Planning and Programming Series; Vol. I: UNIDO-ID/SER. E/4; Vol. II: UNIDO-ID/SER. E/5; Vol. III: UNIDO-ID/SER. E/6.

These are detailed profiles—in terms of capital structures, wage costs, etc.—of 'typical' manufacturing establishments in a wide variety of countries and for a number of products of varying complexity. They could form the basis of a comparative study of technological diversity, though the actual techniques employed in each case are not stated.

UNITED NATIONS INDUSTRIAL DEVELOPMENT ORGANIZATION: *The Establishment of the Brick and Tile Industry in Developing Countries*, UNIDO ID/15, Sales No.: E.69.II.B.19, New York, 1969. Also, original working document by H. W. H. West, ID/WG.16/7, July 1968. Bibliography.

A comprehensive survey of the range of technologies available at each stage in brick-making—winning, hauling, clay preparation, and product manufacture, drying and firing—with comments on the appropriateness of each. 'Before a works is established the market must be investigated and a decision taken on the kind of products to be made. When a suitable clay source is found it inevitably determines the technology. Although there may be several sources of clay equally well situated with respect to the market, not all the processes are equally suitable for all products, and in practice the possible courses of action are few.'

Chapter VI (pp. 101–12) contains productivity and efficiency data of the different processes for typical projects.

UNITED NATIONS INDUSTRIAL DEVELOPMENT ORGANIZATION: *Bicycles: A Case Study of Indian Experience*, Small-scale Manufacturing Studies, no. 1, 1969.

Contains typical production data for firms in the small-scale and in the large-scale sectors in 1966. On account of certain technical innovations and lower overheads certain components can be produced more cheaply by the small-scale sector, that is by firms with total investment in machinery and equipment of up to Rs750,000. Median capital–labour ratios in the large-scale sector are about Rs10,000, and in the small-scale sector about Rs1,500; the respective output–labour ratios are about Rs13,500 and about Rs3,700.

The study gives a detailed breakdown of production costs for plants producing 25,000 and 15,000 bicycles p.a. respectively. There are also detailed suggestions as to how bicycle production should be undertaken under differing conditions.

UNITED NATIONS INDUSTRIAL DEVELOPMENT ORGANIZATION: *Report of Expert Group Meeting on the Selection of Textile Machinery in the Cotton Industry*, UNIDO, Vienna, October 1967, ID/WE. 8/1.

Describes the levels of technology for the spinning and weaving of carded

cotton and presents quantitative data for three hypothetical mill process flows, 'conventional' (*circa* 1960), 'intermediate', and 'automated'. The production level (470,000 square yards of 50-in. fabric per week) was chosen so as to be large enough to justify investment in more modern machinery.

Personnel requirements for the three levels are in the ratio 171:131:100, while horsepower requirements are in the ratio 100:121:124. Equipment costs would vary, but would be approximately in the ratio 100:123:180. There would, however, be savings through inventory reduction on auxiliary equipment for the automated machinery—ratio 118:108:100—and through reduction of space requirements—physical ratio 121:110:100.

The Group recommended the conventional level as most appropriate for developing countries, and strongly recommended against the automated level, for technical reasons as much as anything else.

The study demonstrates how an industry's technology can change radically in only seven years.

UNITED NATIONS SECRETARIAT: 'Choice of Capital Intensity of Industrial Planning', *Industrialization and Productivity*, Bulletin no. 7 (1964), pp. 25–33.

Lists the following industries as being 'technologically flexible': cloth-weaving, woodworking, cotton spinning, clothing, foodstuffs, rubber products, bricks, roofing tiles, certain chemicals, brass utensils, and steel furniture. Also industries which involve the production and assembly of components—radios, TV sets, bicycles, agricultural equipment—can be put out to sub-contractors. The use of second-hand machines and innovations in process layout can help in spreading resources more widely.

Perhaps the greatest scope for reducing capital-intensity exists in scaling down operations where this is possible without greatly increasing operating costs. For instance, ammonia plants can be designed for 60 tons daily capacity where 250 tons is the normal size. Made in separate sections mounted on skids they take less than thirty days to install and involve production costs of about $36 per short ton, compared with $32 for a standard plant (see entry for P. Foster and D. Wood). Similarly, midget oil refineries with capacities of under 10,000 barrels per day, compared with a previous minimum of 25,000 barrels, have been developed. This was made possible by a simplified flow scheme and by the fact that each processing unit serves at least two important functions instead of one.

WELLS, L. T.: 'Economic Man and Engineering Man: Choice of Technology in a Low Wage Country', *Public Policy*, Summer 1973.

Based on a survey of fifty light manufacturing plants in Indonesia in six industries—plastic sandals, cigarettes, soft-drink bottling, bicycle and pedicab tyres, flashlight batteries, and woven bags—data covered four or more plants producing comparable products. The employment potential of techniques for different levels of capital-intensity can be seen from the

SECTION 2

Studies containing aggregate data on relevant ratios

ASIAN DEVELOPMENT BANK: *Southeast Asia's Economy in the Nineteen Seventies*, Longman, 1971.

Gives figures for employment, exports, and investment in Kaoshiung, the free trade and investment zone in Taiwan established in 1965. At the end of 1969 28,803 people were employed with investment of U.S. $36 million by companies and $7·7 million infrastructural investment (p. 307).

BHATT, V. V.: 'Capital–Output Ratios of Certain Industries: A Comparative Study of Certain Countries', *Review of Economics and Statistics*, 1954, pp. 309–19.

This article later became chapter 2 of the author's book *Employment and Capital Formation in Underdeveloped Economies* (q.v.).

BHATT, V. V.: 'Employment and Capital Intensity', *Indian Economic Journal*, October 1954, pp. 142–54.

This article later became chapter 5 of the author's book *Employment and Capital Formation in Underdeveloped Economies* (q.v.).

BHATT, V. V.: 'Capital Intensity of Industries: A Comparative Study of Certain Countries', *Bulletin of the Oxford University Institute of Economics and Statistics*, May 1956, pp. 179–94.

This article later became chapter 3 of the author's book *Employment and Capital Formation in Underdeveloped Economies* (q.v.).

BHATT, V. V.: *Employment and Capital Formation in Underdeveloped Economies*, Orient Longmans, 1960.

Chapter 2 compares the capital–output ratios of a number of industries in Mexico, Peru, India, U.S.A., Australia, Canada, New Zealand, and S. Africa for the years 1939, 1946, and 1949. Even allowing for the influence of certain 'nontechnological' factors—depreciation rates, plant and equipment price variations, under-maintenance, under-utilization, and output price variations—it would appear that the capital–output ratios of the industries of an LDC are not significantly lower than those of the corresponding industries of at least some of the developed economies.

Chapter 3 argues that although the capital–output ratios of industries in LDCs may not be lower than in developed economies, nevertheless, their capital–labour ratios are considerably lower on account of

under-maintenance, defective manufacturing conditions, and inefficient technical and administrative control, even though the *nature* of the plant and equipment is much the same as that in use in developed economies.

Chapter 5 contains data on capital-intensity (but measured by horse-power per worker) in various industries in U.S.A., Canada, Japan, and U.K. during the period 1899–1939.

CREAMER, D.: *Capital and Output Trends in Manufacturing Industries, 1880–1948*, National Bureau of Economic Research, 1954.

This aggregate analysis establishes that there has been a definite and substantial decline in the real capital–output ratio (for both fixed capital and working capital) in U.S. manufacturing as a whole (and in nearly every sector) since the decade 1909–19. Changes in size structure of establishments or firms fail to provide an explanation of the reversal. The author ascribes the reversal to the altered character of technological innovations broadly defined to include managerial changes which since around 1909 have predominantly had the effect of making equipment operate more efficiently, rather than of displacing other factor inputs.

CUMPER, G. E.: 'Labour Productivity and Capital–Labour Ratios in Jamaican Manufacturing Industry: Their Relation to the Problem of Selective Industrialisation', *Social and Economic Studies*, February 1953, pp. 61–86.

Presents data from the Jamaican Census of Manufactures of 1946. The industrial categories analysed are: (*a*) assembly and miscellaneous; (*b*) primary products; (*c*) bulk process. The following table contains some of the results:

	Bulk process (£)	Assembly (£)	Primary (£)
Average net product per worker	346	248	107
Fixed capital per worker	539	140	78
Net product per £100 of fixed capital	64	177	137
Average annual wage	102	95	56
Wage bill per £100 of fixed capital	18	73	73

In the bulk-process industries the larger establishments tend to show a higher net product per worker than the smaller but a lower net product per £100 of fixed capital and a lower wage bill per £100 of fixed capital. Except in the primary-product industries there is a general tendency for the larger establishments to pay a higher average annual wage.

KHAN, A. R.: 'Some Problems of Choice of Techniques in a Mixed Economy', in *Economic Development in South Asia*, ed. E. A. G. Robinson and M. Kidron, Macmillan, 1970, pp. 199–212.

Indicates the magnitude of the under-pricing of capital in Pakistan in the

1960s in relation to social cost through low interest rates and overvalued exchange rate. Effective rates of interest taking both factors into account were 3·5 to 5 per cent. Potential social return to capital was estimated as at least 10 per cent. The accounting wage was probably lower than the market wage. Compares I/L ratios in selected industries in East and West Pakistan with ratios for Japan in 1955. For most industries the Pakistan ratios were substantially in excess of the Japanese ratios. East Pakistan, where wages were lower, generally had lower I/L ratios than West Pakistan. Under-utilization of capacity also contributed to high ratios in Pakistan.

KHAN, A. R.: 'Capital Intensity and the Efficiency of Factor Use', *Pakistan Development Review*, vol. 10 (1970), pp. 232–63.

Examines the capital-intensity of Pakistani industries by sector in terms of fixed capital–labour ratios in 1962/3 and 1965/6. Coefficients are given for East and West Pakistan separately, and for large-, medium-, and small-scale industries. The rankings remained much the same for 'full-capacity capital–labour ratios'. The capital–labour ratios in manufacturing industries are compared with those for Japan and the U.S.A.; there were significant differences in the sectoral ranking of capital-intensities between the three countries.

Fertilizers, paper, and petroleum products all had very high coefficients, followed by cement, sugar, cigarettes, and edible oils; leather and leather products, metal products, wood, cork, and furniture all had very low coefficients. Coefficients were generally lower in East than in West Pakistan, with the exceptions of sugar, paper, machinery, and cement. With the exception of basic metals, coefficients were higher for both regions of Pakistan than for Japan, particularly in the case of textiles.

KILLICK, A.: 'Manufacturing and Construction in Ghana', in Birmingham, W., Neustadt, I., and Omaboe, E. N.: *A Study of Contemporary Ghana*, George Allen and Unwin, 1966, chapter 12 (pp. 274–93).

Contains information about sub-sectors of manufacturing and about the construction sector in Ghana. The two industries with the largest reinvestible surpluses (beverages and tobacco) are also the largest in terms of value added, though the causation could run either way. There is only a weak correlation between profitability (net margin as a percentage of gross output) and labour-intensity (depreciation as a percentage of labour costs), though the author senses that they may be positively correlated in the six largest groups.

Data on labour productivity, profitability, and size suggest that appreciable economies of scale exist, taking manufacturing as a whole. Historical data on date of commencement of operations of establishment and present level of sales cast doubt on the infant industry argument for protection.

MASON, R. H., and SAKONG, I.: 'Level of Economic Development and Capital–Labour Ratios in Manufacturing', *Review of Economics and Statistics*, vol. 53 (May 1971), pp. 176–8.

A cross-sectional regression analysis comparing the level of capital-intensity of eleven developing countries with that of five developed countries.

The variables included in the model are population, *per capita* product, and capital-intensity defined as installed horse-power capacity per person employed. The main conclusion is that 'the capital-intensity of developing countries is relatively too high given factor endowments and market size.' In the absence of more refined data and more complete time series, it was not possible to test the various possible explanations, viz.: factor market price distortions, technical fixity, product market price distortions, and statistical bias due to under-utilization of capital. Little support was found for the hypothesis (H. J. Bruton: 'Growth Models and Underdeveloped Economies', *Journal of Political Economy*, vol. 63, no. 6 (August 1955)) that lack of technical know-how may force developing countries to pass through a period of capital-deepening before it becomes possible to employ technologies which are capital-saving.

MEHTA, M. M.: *Capital Intensity of Manufacturing Industries in Some Selected Countries of the ECAFE Region*, Asian Institute for Economic Development and Planning, Bangkok, 1969, Special Course D. III, Human Resources Development, Statistical Supplement No. 4, 69/Spl/D.III.

Lists statistics of capital-intensity on two definitions—fixed assets per paid employee and net value added per paid employee—for all manufacturing and by sector of manufacturing for Taiwan, India, Korea, Malaya, Pakistan, Philippines, Thailand, and Japan.

MEHTA, M. M.: 'Employment Aspects of Industrialisation with Special Reference to Asia and the Far East', unpublished mimeo report, 1970. Summarized in *Development Digest*, January 1972, pp. 87–93.

Presents a geographical picture of capital-intensity (fixed capital/labour) in manufacturing in selected ECAFE countries. In almost all industry groups, capital-intensity is much higher in Japan, the Philippines, and Taiwan than in Pakistan, India, Korea, and Thailand; in general, chemicals (including petroleum products and fertilizers), non-metallic minerals (cement), paper, and metal products are the more capital-intensive industries; 'food, tobacco, and beverages' is more capital-intensive than textiles, rubber, and even machinery and transport equipment; and certain groups of manufactures appear to be highly capital-intensive in some countries, e.g. chemicals in Taiwan, metal products in India, paper in Thailand, food and textiles in the Philippines, and chemicals and machinery in Japan.

The author presents data which suggest that labour-intensive industries do not have high capital–output ratios, though no account is taken of working capital. He lists industries with both high labour-intensity and low capital requirements (for another such list see also the entry for R. B. Sutcliffe).

Cites a study by Dr. T. Y. Wu, 1963 (no title given) which concluded from data for India, Pakistan, the Philippines, and Japan that there is no definite positive or negative correlation between operating profits by industry group and capital-intensity. The author argues that Korean data support this finding.

NETHERLANDS ECONOMIC INSTITUTE: 'Capital–Labour Ratios of Certain Industries in Some Countries: A Progress Report', mimeo, Division of Balanced International Growth, Rotterdam, Publication 1/55, December 1955.

Contains estimates of total capital (fixed plus working): numbers employed for eleven industries in four countries:

	U.S. $'000 (1950 prices)			
	U.S.A.	Mexico	Colombia	India
Flour and grist mill products	39·1	10·4	19·9	5·6
Bread and bakery products	5·0	1·7	1·3	3·5
Sugar refining	26·8	8·2	12·4	2·6
Starch	—	9·4	3·8	3·3
Alcoholic beverages	16·0	6·6	18·0	6·1
Tobacco manufactures	12·4	8·6	2·0	—
Iron and steel	32·1	10·8	5·4	5·7
Woodpulp, paper, and paper products	10·2	8·9	4·8	6·6
Printing and publishing	5·1	3·5	5·1	—
Cotton yarn and cloth	8·7	2·1	6·2	1·8
Rubber products	7·0	3·4	6·1	—

ROSEN, G.: 'Capital–Output Ratios in Indian Industry', *Indian Economic Journal*, October 1956, pp. 107–22.

Presents data on the capital–output ratios in cement, paper, iron and steel, and cotton textiles over the period 1937–40 to 1947–52. The deflated series (industry averages) for Gross Fixed Assets : Net Value Added of Output are:

	1937–40	1941–6	1947–52
Cement	2·9	3·0–3·5	3·2–3·8
Paper	6·2–6·3	6·4–6·7	7·3–10·0
Iron and Steel	3·3–3·5	3·4–4·1	4·3–5·0
Cotton textiles:			
Bombay	3·4–3·9	2·3–3·2	4·8–5·0
Ahmedabad	3·5–4·4	3·0–3·8	4·6–6·6
Others	4·4–5·0	2·8–3·3	6·1–6·6

SALTER, W. E. G.: *Productivity and Technical Change*, Cambridge University Press, 1969.

Part I develops a theoretical analysis of the relationships between movements of productivity, prices, costs, wages, and investment in industries experiencing a continuous flow of new techniques. Part II examines the relationships between these variables in a number of British and American

industries over the period 1923–50. In chapter X the author develops an explanatory hypothesis.

'The analysis has suggested that, to explain the data, primary emphasis must be placed on technical progress and economies of scale. These are causes of labour productivity which extend their influence to all factors and so can account for the behaviour of costs. Increases in the personal efficiency of labour and factor substitution cannot explain the data by themselves although, in the case of factor substitution at least, it is possible (and indeed likely) that an important contribution has been made to the observed increases in productivity.'

SUTCLIFFE, R. B.: *Industry and Underdevelopment*, chapter 5, pp. 140–97, 'Technology and Industrialisation', Addison-Wesley, London, 1971.

Discusses the limitations of theoretical treatments of the problem of choice of industrial technique. There is also a survey of the empirical work on the subject, and the author offers informed hunches of his own as to which sort of techniques are most appropriate in individual industries in LDCs. There is a table, compiled from a number of sources, giving information about the capital-intensity of twenty subdivisions of manufacturing industry for seven regions of the U.S.A. in 1954 and 1958, and within four countries (U.S.A., Mexico, Colombia, and India) in 1945/50. The author suggests that a range of techniques is most likely to be available in tobacco, paper products, leather and leather goods, some rubber products, soap, paint and explosives, and transport equipment.

SECTION 3

Studies estimating production functions

ARROW, K. J., CHENERY, H. B., MINHAS, B. S., and SOLOW, R. M.: 'Capital–Labour Substitution and Economic Efficiency', in *The Review of Economics and Statistics*, August 1961, pp. 225–50.

From data for twenty-four manufacturing industries in a sample of nineteen countries the authors conclude that 'the value added per unit of labour used within a given industry varies across countries with the wage rate.' Empirical evidence further establishes varying degrees of substitutability in different types of production. The authors are thus led to attempt to derive a mathematical function having the properties of (i) homogeneity, (ii) constant elasticity of substitution between capital and labour, and (iii) the possibility of different elasticities for different industries. The function they derive is the constant-elasticity-of-substitution (C.E.S.) production function, which includes the Leontief and Cobb-Douglas functions as special cases, and contains three parameters, the substitution parameter, the distribution parameter, and the efficiency parameter. From information on the direct use of capital they suggest that the efficiency parameter varies from country to country but that the other two are constants for each industry.

See also the entry for C. St. J. O'Herlihy.

BEHRMAN, J.: 'Sectoral Elasticities of Substitution Between Capital and Labor in a Developing Economy: Time Series Analysis in the Case of Post-war Chile', *Econometrica*, vol. 40, no. 2, March 1973.

BOWLES, S.: 'Aggregation of Labor-Inputs in the Economics of Growth and Planning: Experiments with a Two-level C.E.S. Function', *Journal of Political Economy*, vol. 78, no. 1, January–February 1970.

CHENERY, H. B.: 'Capital–Labour Substitution in Metalworking Processes', Stanford Research Project for Quantitative Research in Economic Development, Memorandum No. C-3, Stanford, February 1957, mimeo.

Suggests that by assigning an investment cost to each machine tool in the analysis of H. M. Markowitz and A. J. Rowe (q.v.), it would be possible to use their data to construct capital–labour substitution functions for each individual task. With such functions, it should in turn be possible to make *ceteris paribus* predictions as to how methods of production

might vary from one point in time or space to another, depending on the relative prices of the two substitutable inputs, capital and labour.

See also entries for M. Kurz and A. S. Manne, for K. J. Arrow *et al.*, and for C. St. J. O'Herlihy.

DANIELS, M.: 'Differences in Efficiency Among Industries in Developing Countries', *American Economic Review*, vol. 59, no. 1 (March 1969).

Cross-section C.E.S. production-function estimates for seventeen industries in eight developing countries; widely dispersed results ranging from 0·4 to 1·8 for elasticity of substitution.

DERVIS, K.: 'Substitution, Employment and Intertemporal Equilibrium in a Non-Linear Multi-Sector Planning Model for Turkey', New Jersey, unpublished doctoral dissertation, Princeton, 1973.

DIWAN, R. K., and GUJERATI, D. N.: 'Employment and Productivity in Indian Industries—Some Questions of Theory and Policy', *Artha Vijnana*, vol. 10, no. 1, March 1968.

Estimates C.E.S. production functions for twenty-eight industries in India.

ERIKSSON, J. R.: 'Wage Change and Employment Growth in Latin American Industry', Williams College, Research Memorandum, 36, 1970.

Cross-section estimates across industries within countries for thirty to seventy-five industries in five Latin American Countries. Average elasticity of substitution about 0·7.

JEROME, H.: *Mechanization in Industry*, New York, National Bureau of Economic Research, 1934.

Summarizes studies of the process of substituting capital for labour in a number of industries.

KATZ, J. M., *Production Functions, Foreign Investment and Growth*, North Holland, Amsterdam, 1969.

Study of fifteen industries in Argentina, estimating C.E.S. production functions. Cross-section estimates average one; time series 0·3.

KURZ, M., and MANNE, A. S.: 'Engineering Estimates of Capital–Labour Substitution in Metal Machining', in *American Economic Review*, September 1963, pp. 662–81.

Modifies the data presented by H. M. Markowitz and A. J. Rowe (q.v.) eliminating all technically inefficient techniques, and develops the suggestion of H. B. Chenery (q.v.) to construct capital–labour substitution

functions for each individual task. The authors explain the 290 estimates they derive from Markowitz and Rowe's data within the context of a least-squares regression analysis for three models, two based on the Cobb–Douglas production function, the third on the C.E.S. production function.

See also entries for K. J. Arrow *et al.* and for C. St. J. O'Herlihy.

MARKOWITZ, H. M., and ROWE, A. J.: 'A Machine Tool Substitution Analysis', in A. S. Manne and H. M. Markowitz (eds.): *Studies in Process Analysis*, Cowles Foundation, Yale, 1963, chapter 12, pp. 313–51.

Uses linear programming techniques to analyse the possibilities for direct substitution between machine tools. These engineering estimates, based on U.S. data, are intended to represent the number of pieces per day that can be produced by one worker utilizing a choice of 115 alternative machine tools to perform a total of 129 alternative metal-removal tasks. These tasks are stated in terms of the elementary operations performed, rather than in terms of end products.

See also entries for H. B. Chenery, for M. Kurz and A. S. Manne, for K. J. Arrow *et al.*, and for C. St. J. O'Herlihy.

MINHAS, B. S.: *An International Comparison of Factor Costs and Factor Use*, North-Holland Publishing Co., Amsterdam, 1963.

Aims to 'suggest empirically usable relations for the analysis of substitution between capital and labour, to ascertain, quantitatively, the differences in the cost of labour and capital in a fairly large number of manufacturing industries and to derive numerical estimates of the elasticity of substitution between the two inputs, and to show the significance of these empirical findings for problems of international trade and economic development'.

Chapter 3 estimates the elasticities of substitution between labour and other inputs on the basis of regressions of labour inputs on wage rates for twenty-four industries in nineteen countries. For four industries the value of the elasticity of substitution lies between 0·72 and 0·80, for seventeen between 0·80 and 0·92, and in only three industries is it greater than 0·92.

Chapter 4 compares the ranking of I/L ratios by industry in Japan and the U.S.A. and shows some factor reversals.

MORAWETZ, D.: 'Employment Implications of Industrialisation in Developing Countries', mimeo, IBRD, 1973.

Summarizes (pp. 27–32) the results of C.E.S. studies and shows that 'estimates of elasticity of substitution at the two-digit level for the U.S. and a number of developing countries do not display consistent industry

rankings, and thus do not help in identifying industries which have relatively high or low substitution elasticity.'

Also summarizes work of V. E. Tokman (published in Spanish) who estimates the increase in employment associated with choosing labour-intensive techniques in some industries in Venezuela.

O'HERLIHY, C. St. J.: 'Capital/Labour Substitution and the Developing Countries: A Problem of Measurement', *Bulletin of the Oxford University Institute of Economics and Statistics*, August 1972, pp. 269–80.

Argues that the capital–labour substitution elasticity is probably much smaller than it has generally been assumed to be, and suggests that the methodology generally employed is at fault. In particular, the author criticizes three assumptions of the production function approach:

(*a*) the assumption of perfectly competitive markets for the inputs means that there must be constant returns to scale to ensure that income and output are equal;

(*b*) the treatment of labour, capital, and output as homogeneous units is unrealistic when an industry or a whole economy is being considered;

(*c*) the available ratios for an industry will be averages of a series of techniques reflecting different technologies, different economy of scale factors, different efficiency ratios, etc. Moreover, developing countries are often lacking in data on capital.

The constant elasticity of substitution (CES) production function avoids the problems associated with estimating capital stock, but at the expense of the following assumptions:

(*a*) constant returns to scale;

(*b*) technological change with a constant capital–labour ratio, and at a constant rate;

(*c*) constant elasticity of substitution at all points on the production function regardless of time or output size;

(*d*) entrepreneurs optimize their positions with respect to the currently existing production function;

(*e*) the output–labour ratio is related to the average wage and is independent of the capital–labour ratio.

The author discusses empirical work which throws doubt on these assumptions.

PACK, H.: 'The Employment–Output Trade-Off in LDC's: A Micro-economic Approach', mimeo, Swarthmore College, University of Nairobi, 1972.

Constructs a unit isoquant from data collected in UNIDO: *Profiles of Manufacturing Establishments* (q.v.), measuring labour in terms of total man-hours involved in direct production, capital in terms of the dollar amount of equipment valued at 1964 replacement cost estimates (local costs being converted to dollars at the existing official exchange rate), and output in terms of domestic value added. The countries for which

data were used were France, India, Japan, Israel, and Yugoslavia. The main results are:

	Elasticity of substitution	Presence of economies of scale	Skill differentials among efficient firms	Age differences in equipment among efficient firms
Bicycles	3·5	No	No	No
Wheat milling	2·7	No	Yes	No
Paints	1·4	No	No	Yes
Tyres	1·7	No	Yes	Yes
Cotton spinning	1·1	No	No	Yes
Woollen yarns	1·4	No	No	No

ROEMER, M.: 'The Neoclassical Employment Model Applied to Ghanaian Manufacturing', in F. J. Stewart (ed.), *Employment, Income Distribution and Development*, Frank Cass, 1975; also in *Journal of Development Studies*, special issue, January 1975.

Pools cross-section and time series for seven industries with firm data for Ghana and estimates a C.E.S. production function. Estimates of elasticity of substitution between 0·7 and 1·3.

TIDRICK, G. M.: 'Wages, Output and the Employment Lag in Jamaica', Williams College, Research Memorandum No. 40.

Time series C.E.S. estimates for six industries in services. Elasticity average 0·6.

WILLIAMSON, J. G.: 'Capital Accumulation, Labor saving, and Labor Absorption Once More', *Quarterly Journal of Economics*, vol. 85, no. 1, February 1971.

Pools cross-section and time series data for six industry groups in manufacturing in the Philippines, and constructs a C.E.S. production function. Most elasticity estimates over one.

SECTION 4

Some studies of small-scale industries

AUBREY, H. G.: 'Small Industry in Economic Development', in *Social Research*, September 1951, pp. 269–312; bibliography.

Argues, with reference to the experience of the Far East, that small industry in developing countries has short-run advantages, 'and may even be able to pay its way over a longer period'. Small-scale enterprises are often at an advantage in saving investible resources, in the manufacture of certain high quality and non-standardized products, and where short production runs and flexibility in adjusting to changes in demand are required. 'Small industries in the rural regions of underdeveloped countries have the important economic and social function of relieving agricultural under-employment and seasonal unemployment. Increase in local incomes . . . can spread the benefits of industrialization . . . and help create a wider market for all industrial products. And during the essential period of transition from subsistence to market agriculture, a local labour force can shift between farming and manufacturing, as seasons and demand dictate.'

BOTTOMLEY, A.: 'The Fate of the Artisan in Developing Economies', *Development Digest*, vol. 5 (April 1967), pp. 31–59.

Explores the possibility of displaced artisans becoming innovators in agriculture and small industry.

DANDEKAR, V. M.: 'The Role of Small-Scale Industry in the Indian Experience', in *Education, Employment and Rural Development*, ed. James Sheffield, East African Publishing House, 1967.

Describes Indian Government policy towards small-scale industry emphasizing the dualistic approach of the second five-year plan with its emphasis on heavy industry for investment goods and village industries for consumer goods. Argues that village industries require no less capital and more labour and are thus based on an inferior technology. Modern small-scale industry, based on modern technology, is distinguished from large-scale industry by greater significance of self-employment. Describes Ambar Charkha experiment. In 1957 an inquiry found that on average Ambars worked four hours a day 200 days a year; average estimates of production were one-quarter of original expectations. The failure of Village Industries in the second five-year plan was attributed to poor technology 'incapable of giving the worker even bare subsistence'. Third Plan emphasized modern small-scale industry, but this was similar to conventional modern industry in employment implications.

DHAR, P. N.: *Small-Scale Industries in Delhi*, Asia Publishing House, 1958.

Detailed study of 326 small enterprises—employing 1–20 persons, with a minimum block capital of Rs250—in 13 Delhi industries during 1953–4, by questionnaire and/or direct questioning.

Takes the use of electricity as a criterion for level of technology. Capital–output ratios, calculated on four separate definitions of capital and output, suggested that advances in technology did not increase the capital–output coefficient. However, estimates of capital–labour ratios, calculated on two definitions, suggested that technological advance involves an increase in the capital–labour ratio.

A rough indication of surplus per worker (average net value added minus the average wage) is also given. An interesting result regarding wages was that wage rates did not differ appreciably between non-power and power-using units, increased real income in the latter case being obtained in the form of greater leisure and security as provided by the Factories Act.

A summary of the main findings is contained in P. N. Dhar, 'Some Aspects of Technical Progress in Small Scale Industries in Delhi', *Indian Economic Review*, vol. 3 (1956–7), pp. 67–76.

DHAR, P. N., and LYDALL, H. F.: *The Role of Small Enterprises in Indian Economic Growth*, Asia Publishing House, New York, 1961.

Distinguishes between three types of small enterprise: cottage industries using traditional methods to make traditional products, and using local sources of raw materials and family labour, which sell their products in local markets; modern small firms using modern techniques to produce modern products, and using raw materials from distant sources and hired labour; intermediate enterprises using more or less traditional techniques to produce more or less modern products.

Data from the 1956 Indian Census of Manufactures on output–capital ratios suggest that small enterprises can be more capital-saving than large; output is defined as annual net value added and capital as net fixed capital at book value plus cash at end of year:

	Average Daily No. of Employees				
	20–49	50–99	100–249	250–499	500+
Wheat flour	0·23	0·44	0·35	0·80	—
Rice milling	0·32	0·34	0·30	(0·24)	—
Vegetable oils	0·20	0·24	0·22	0·30	(0·31)
Soap	0·13	0·18	0·55	(0·09)	0·71
Tanning	0·28	0·39	0·38	0·55	(0·32)
Cotton textiles	0·24	0·50	0·23	0·41	0·63
Bicycles	0·51	0·58	0·39	0·51	0·49
Electric fans	0·36	0·33	0·53	0·41	0·30

(Figures in brackets relate to one factory only.)

Modern small industries rely heavily on the external economies of a good local market, good supplies of raw material from local dealers, etc. Therefore from the point of view of decentralization large and medium firms offer greater possibilities.

Wages and profit per unit of capital are both lower in small firms than in large, and the differential is greater in developing than in developed countries, as the following table indicates:

No. of employees	Average wage and salary payments per employee (index numbers)			
	India (1955)	Japan (1952)	Britain (1949)	U.S.A. (1947)
4–9	—	39	—	73
10–19	47	46	84	79
20–49	51	53	83	84
50–99	55	60	84	86
100–199	72	69	85	86
200–499	85	83	86	88
500–999	88	96	89	90
1,000+	100	100	100	100

There is much to be said for the traditional village industries from the standpoint of saving capital, especially where the capital is already in existence. However, as incomes rise traditional products come to be considered inferior and there is a limit to the extent to which demand can justifiably be diverted through fiscal measures. The authors suggest that this limit had been surpassed with certain products such as khadi.

DI TULLIO, K. A.: 'The Role of Small Industries in the Political Economy of Pakistan', unpublished doctoral dissertation, Syracuse, 1972.

Shows small industries to be more labour-intensive than large.

MEHTA, B. V.: 'Size and Capital Intensity in Indian Industry', *Bulletin of the Oxford University Institute of Economics and Statistics*, August 1969, pp. 189–204.

Criticizes J. C. Sandesara's (q.v.) findings in a previous article, and in particular that there is no positive correlation between size (numbers employed) and capital-intensity in terms of the capital–labour ratio, but that a positive correlation exists between size and the output coefficient and also between size and the surplus–capital ratio. Mehta points out that Sandesara looked only at the factory constituents of the small-scale sector, which account for only about 10 per cent of those employed in the sector.

He finds wide fluctuations in the capital-labour ratio for the smallest size group compared to the largest in the ten industries analysed by Sandesara during the period 1953–8 and suggests that they can largely be attributed to the extent of capacity utilization.

Mehta offers his own analysis of thirty-two industries for the period 1960–3, using a fixed capital criterion of size. He concludes that smaller factories are both less capital-intensive and more capital-productive than large.

NATIONAL COUNCIL OF APPLIED ECONOMIC RESEARCH: *Study of Selected Small Industrial Units*, New Delhi, 1972.

Studies the economics of operation of small enterprises on the basis of a survey covering 159 enterprises selected from twenty-two industrial groups in Indian manufacturing. It is estimated that the small-scale sector accounts for 52 per cent of value added in manufacturing. For comparison, data from the Annual Survey of Industries (A.S.I.) comparing ratios of large-, medium-, and small-scale enterprises, 1960–5, is included.

A.S.I. data:	Rs	
Small enterprises:	*1960*	*1965*
Fixed capital per employee	1,727	2,017
Value added per employee	1,882	2,358
Value added per unit fixed capital	1·09	1·17
Medium enterprises:		
Fixed capital per employee	2,654	4,044
Value added per employee	2,742	3,815
Value added per unit fixed capital	1·03	0·94
Large enterprises:		
Fixed capital per employee	7,051	17,753
Value added per employee	3,801	5,216
Value added per unit fixed capital	0·54	0·29

Data for small enterprises surveyed:	*1969–70*
Total capital per employee	13,554
Fixed capital per employee	6,393
Value added per employee	6,456
Value added per unit fixed capital	1·01

According to the A.S.I., I/L and O/L ratios rise and O/I fall as the size of enterprise increases. The results of the survey did not tally completely with the A.S.I. figures; some of these differences were attributed to different industrial coverage, since the A.S.I. covers fifty-eight industries. The survey includes data by industry group of fixed and working capital, a breakdown of different elements of each, capital–labour ratios, labour productivity, wage and salary payments, production and distribution costs, sales and operating profit, consumption of indigenous and imported raw materials, financial structure, capacity utilization, and reasons for working below capacity. For the sample as a whole working capital formed about 53 per cent of total capital. Local plant and machinery accounted for three-quarters of total plant and machinery. Exports accounted for 8 per cent of the sales of all industries; these were heavily concentrated among five of the twenty-two industries. Nearly 90 per cent of raw material consumption was of local origin. Wage and salary

payments accounted for 37 per cent of value added. Forty per cent of the units reported returns below 10 per cent on productive capital (of which 17½ per cent reported a loss). In the majority of cases the units were operating below 50 per cent of capacity utilization. The most important reasons given were shortage of raw materials, inadequate finance, lack of demand, and obsolete equipment. The aggregate figures given here conceal substantial intra- and inter-industry variations for which data are reported in this book.

SANDESARA, J. C.: 'Scale and Technology in Indian Industry', *Bulletin of the Oxford University Institute of Economics and Statistics*, August 1966, pp. 181–98.

This study covers ten major Indian industries over the period 1953–8. On the basis of rank and product-moment correlation coefficients the main conclusions are: that small units may or may not be labour-intensive; that small units have lower output, lower wage, and lower surplus *each* per worker, and also lower output and lower surplus *each* per unit of capital; and that labour-intensive technology has a lower wage per worker, but higher output and higher surplus *each* per unit of capital. Hence the author advocates large-scale and labour-intensive technologies.

See also the entry for B. V. Mehta (*BOUIES*, August 1969) which challenges these findings.

Sandesara defends himself in an article in *BOUIES*, November 1969. In particular he claims that Mehta's data on the Census sector cover more large-scale factories and exclude more small-scale factories than he does in his own sample.

SCHUMACHER, E. F.: *Small is Beautiful: A Study of Economics as if People Mattered*, Blond & Briggs, London, 1973.

Attacks the worship of size in the modern world and suggests that insights into man's economic condition can be had from Buddha and Gandhi as well as from western economics. Part III contains a chapter explaining the rationale of Intermediate Technology.

SHETTY, M. C.: *Small-scale and Household Industries in a Developing Economy*, Asia Publishing House, 1963.

General discussion of the role of small-scale industries citing among other things (i) data on techniques of cotton weaving—see Raj, and A. K. Sen (1968); and (ii) survey of the engineering industry in Bombay City showing that I/L and I/O ratios are lowest for the smallest scale (under 20 employees) and surplus per worker greatest for smallest scale.

The main part of the book reports on a field survey of household and small-scale industries. The sample was selected from three tensils, covering 16 industries. Average employment in 11 household industries varied between 2 and 6; in 5 small-scale industries average employment varied between 4 and 11. Information provided includes data on fixed and

working capital, type of ownership, mode of acquisition, duration of working period, earnings, and nature of indebtedness.

The following were among the findings: working capital varied from 25 to 75 per cent of total capital, with a tendency to account for a greater relative share in household than in small-scale industries. Capital–output ratios were broadly similar between the household and small-scale industries, but the capital–labour ratios and labour productivity were significantly higher among small-scale industries. The gross surplus per worker and per unit of investment was greater among small-scale industries, while, on average, wages were lower in household than in small-scale industries. Family workers accounted for over half the employment in most household industries, and a substantially lower proportion (10–47 per cent) in small-scale industries. Whereas inheritance dominated as a mode of acquisition among household industries, 'newly initiated' dominated among small-scale industries. Most of those involved in small-scale industries relied on their work for full support, while most of those in household industries had supplementary sources of income, especially agriculture. Household industries got most of their skilled employees from among the family; small-scale industries hired most of their skilled employees. Both had substantial amounts of unutilized capacity—capacity utilization ranged on average from 34 to 65 per cent in household industries and was slightly higher among small-scale industries. Lack of finance for working capital was the most important single reason given for idle capacity, followed by lack of demand and raw material and technical difficulties. Over half those interviewed in each household industry reported that they desired to introduce technical improvements. The proportions were greater among small-scale industries. All those wishing for assistance to introduce improvements wanted financial assistance. Fewer wanted technical help. The improvements for which help was sought involved a higher absolute amount of investment in small-scale as compared with household industries: they also involved a greater increase in employment. Some of the household industries' improvements would employ existing workers more fully rather than expanding employment. While the implied marginal I/L ratio was higher for small-scale than for household industries, typically, the differences were proportionately less on the margin than on average.

STALEY, E., and MORSE, R.: *Modern Small Industry for Developing Countries*, McGraw-Hill, 1965.

Chapter 7 discusses small-factory resource use and development strategy. Contains data on output–capital and capital–labour ratios by industry group for U.S.A., Japan, Pakistan, and New Zealand. Also, marginal coefficients for Australia, and incremental output, investment, and labour coefficients for all industries by size group for Australia.

In the U.S.A., and even more so in Japan, most industry groups with a high share of small-plant output tend to have high value added per unit of fixed capital and low fixed assets per employee, although not all industries with these characteristics are small-plant industries; among small-plant groups, non-metallic minerals, food products, and beverages stand out as having higher than usual capital per employee and capital–output coefficients. Among small-plant industries in Pakistan, simple assembly, mixing, and finishing industries show both highest value added

per unit of capital and lowest capital per employee; chemical end products and pharmaceutical products have high O/I, but also relatively high I/L—the same is generally true of 'market-oriented' and 'separable manufacturing' operations, with cement, bicycles, agricultural machinery, and metal articles having especially high I/L: processors of dispersed resources and service industries are about average for all manufacturing.

The authors go on to discuss the conclusions of H. M. Markowitz and A. Rowe's process analysis of metal-machining in A. S. Manne and H. M. Markowitz, *Studies in Process Analysis*, New York, 1963.

TODD, J. E.: 'Size of Firm and Efficiency in Colombian Manufacturing', Williams College, Research Memorandum 41.

Shows low capital–output ratios in small firms.

UNITED NATIONS INDUSTRIAL DEVELOPMENT ORGANIZATION: 'Policies and Programmes for the Development of Small-Scale Industry', *Industrialization and Productivity*, Bulletin no. 14 (1969), pp. 59–74.

Contains information on the incidence of small-scale industries in Japan, India, Pakistan, U.K., and the U.S.A.

In Japan the number of establishments in a sector, labour productivity, the capital–labour ratio, and the wage rate are all closely correlated with size, while the capital–output ratio is not. In Pakistan labour productivity is higher in small-scale industries in printing, chemicals, machinery, and miscellaneous industries. In India small size and low labour productivity are correlated, and both are positively correlated with lower professional and technical labour requirements.

UNITED NATIONS INDUSTRIAL DEVELOPMENT ORGANIZATION: *Small-Scale Industry in Latin America*, U.N., New York, 1969.

Surveys the role and characteristics of small industries in Latin America in the 1960s. Contains data on capital-intensity in terms of horse-power per operative.

VEPA, R. K.: *Small Industry in the Seventies*, Vikas Publications, London, 1971.

Contains chapters discussing the role of small industries in India, Japan, Asia, the Middle East, Africa, and Latin America. Chapter 11, 'Modernisation of Small and Village Industries' surveys the various organizations, especially Indian ones, which have been concerned with encouraging the adoption of improved low-cost techniques in developing countries.

WATANABE, S.: 'Subcontracting, Industrialization and Employment Creation', *International Labour Review*, vol. 104 (July–December 1971), pp. 51–76.

Discusses the advantages of subcontracting as a way of expanding production and employment without recourse to heavy mechanization.

SECTION 5

Choice of technique in China and Japan

ANDO, T.: 'Interrelations Between Large and Small Industrial Enterprises in Japan', *Industrialization and Productivity*, Bulletin no. 2 (1959), UNIDO, pp. 26–35.

Surveys the organizational and legal measures which made the small-industry sector secure in Japan. The exceptionally large number of small enterprises was made possible by the widely available external economies, such as cheap electricity and good transport. These enterprises are mostly located in the countryside and employ low-wage labour working long hours, and also part-time workers. Most work as subcontractors to larger enterprises.

BHALLA, A. S.: 'Technological Choice in Construction in Two Asian Countries: China and India', *World Development*, vol. 2, no. 3, March 1974.

Divides Chinese technological strategy into three stages, Soviet model (high technology) phase (1949–57), the Great Leap Forward phase (1958–60), and the 1960s, and examines choice of techniques in the construction period in that light. Contains comparisons with India.

LEAN, E. C.: 'Innovation in a Choice of Techniques Context: The Chinese Experience, 1958–1970', in the *Bulletin of the Sussex Institute of Development Studies*, vol. 4, no. 2/3, (June 1972), pp. 39–48.

Discusses the Chinese policy of 'technological dualism'—the use of both modern, imported, large-scale, capital-intensive industrial technologies and of traditional, native, small-scale, labour-intensive technologies—and the various approaches adopted to deal with the critical problem of developing a base of technical skills appropriate for innovation in the two sectors. During the period of the 'Great Leap Forward' (1958–60) the emphasis was on production and on 'practice' as opposed to 'theory'. Later it was acknowledged that whereas the worker can devise improvements for that part of technology with which he is familiar, responsibility for technological change and development rests with specialized technical staff, and periods of consolidation by the 'Scientific and Technical Services' are necessary.

HOLLERMAN, L.: *Japan's Dependence on the World Economy*, Princeton, 1967, pp. 49–55.

A brief discussion of the 'status of labor-intensive industry' (chapter 5) which contains data on value added per person employed in each of the major industrial classifications.

HSIA, R., and CHEN, E. K. Y.: 'Technological Change, Economic Growth, and Employment Generation: A Study of the Chinese non-farm Sector, 1950–1965', paper presented to Conference on Technology, Employment and Development, under the auspices of the Council for Asian Manpower Studies, 1973.

Applies C.E.S. production function analysis to the Chinese non-farm sector. Finds a structural break in 1958–9, arguing that the rate of technological change was lower in the second period, when more labour-intensive technology developed locally was used, as compared with the earlier period when capital-intensive technology was imported from abroad.

JOHNSTON, B. F.: 'Agriculture and Economic Development: The Relevance of the Japanese Experience', *Food Research Institute Studies*, Stanford University, vol. 6, no. 3 (1966), pp. 251–312.

In the 1880s Japan, already characterized by a low capital–labour ratio, had a higher rate of growth of employment than of capital. The dual structure of the economy which was developing was consciously fostered. In the plan of 1884 (see Inukai, I., and Tussig, A. R., *Kōgyō Iken: Japan's Ten Year Plan, 1884–94*, University of Alaska (mimeo)) it was stated that 'manufacturers are to be directed to postpone the establishment of a factory with big machines and to pay more attention to the improvement of machines which they now use.'

There were a number of factors which made this policy possible. Among them were: the strong demand which still existed for traditional products; the fact that many of the new farm implements could be manufactured by small workshops; organizational arrangements such as subcontracting, which was in turn made possible by the established cultural values; the increasingly efficient transport and communications systems. LDCs today, however, have a higher rate of population growth, and the technical superiority of the latest processes is often so decisive that it is uneconomic to use more labour-intensive technologies even when relative factor prices differ enormously.

Dual development such as Japan's taps sources of capital and entrepreneurial ability. The same process was evident in Pakistan during the period of the expansion of tubewell irrigation where the small agro-industries which grew up not only provided non-farm employment but also made available essential farm inputs at much lower capital costs and smaller foreign-exchange content than would have been the case if exclusive reliance had been placed, as originally contemplated, on large-scale public tubewell projects utilizing larger and more sophisticated pumps and motors (see Falcon and Gotsch, *Agricultural Development in Pakistan: Past Programs and Future Prospects*, Harvard Center for International Affairs, 1966).

OKITA, S.: 'Choice of Techniques', *Industrialization and Productivity*, Bulletin no. 4 (1961), UNIDO, pp. 21–7.

A macro-economic discussion of the historical development of the agricultural, transport, and manufacturing sectors in Japan. Contains data

on capital-intensity (fixed capital per worker) and wage level by size of enterprise and by sub-sector in the 1950s.

OKITA, S.: 'Choice of Techniques: Japan's Experience and its Implication', in K. Berrill (ed.), *Economic Development with Special Reference to East Asia*, Macmillan, 1964, pp. 376–85.

Points out the special conditions pertaining in the Soviet Union after 1917 (defence needs and labour scarcity in agriculture) which led to development policies which favoured heavy industry, and suggests that Japanese development is more relevant to the problems of densely populated East Asia today.

In agriculture the major technological developments were in weeding, plant breeding, drainage, irrigation, and the use of manure, cultivation and other equipment being introduced at a much later stage.

In transportation, use of single-track railways and shipping both helped to save capital and foreign exchange. Having historically used only a few draught animals the roads were not developed for transportation of goods. For geological and topographical reasons roads would have been expensive to build, whereas nearly all cities and factories were located on the coast and railways are especially economical where the population is dense.

The armaments programme led to the growth of the shipbuilding industry which led to the establishment of an iron and steel industry, run and subsidized by the government till the 1930s. The textile industry switched from using home-produced cotton to using cheaper imported cotton. Then sericulture grew up and helped to lay the foundations for the rayon industry. The machine-tools industry grew out of military needs and the demands made on civilian and mining repair shops.

Finally, the author discusses the size-structure of Japanese industry and the sub-contracting system (see entries for Watanabe).

RANIS, G.: 'Factor Proportions in Japanese Economic Development', *American Economic Review*, September 1957, pp. 594–607.

Offers an analysis of the broad trends of Japanese development. During the period 1868–97 the participation rate in the (formal) economy increased steadily, *despite* the fact that the total population was growing fast. Moreover, it is certain that increases in working hours and decreases in disguised unemployment also undoubtedly took place.

The development of the subcontracting system meant that light industry grew up as an extension of agriculture, encouraged by the acceptance of very low wages by the peasantry. In the latter years of the nineteenth century the relative scarcity of capital increased, a trend which was reversed in the twentieth century. This is indicated by the table on p. 64.

The most convincing evidence that the persistence (and development) of cottage industries was not simply the irrational survival of the old ways was its virtual absence in the cotton-spinning industry where the new methods were very much more efficient than the old. Here capital-saving took the form of intensive utilization of equipment, and use of cheap labour in auxiliary tasks.

	Ratio of capital goods price to money wage index	Ratio of real capital goods price to real wage index
1887	2·68	—
1888–92	2·78	—
1893–7	3·13	2·46
1898–1902	3·28	2·70
1903–7	3·35	2·64
1908–12	2·41	1·96
1913–17	3·10	2·31
1918–22	2·30	1·82
1923–7	1·37	1·16
1928–32	1·00	1·00
1933–7	1·08	0·99

RISKIN, C.: 'Local Industry and Choice of Techniques in Planning of Industrial Development in Mainland China', in UNIDO: *Planning for Advanced Skills and Technologies*, U.N. Industrial Planning and Programming Series No. 3, ID/SER.E/3, Sales No. E.69II.B.8, New York, 1969, pp. 171–80.

Most of the theoretical analysis on the choice of techniques has been carried out at a level of abstraction which has led to an 'either–or' result so that the technological pluralism of the Chinese—using a mixture of techniques to produce the same products (or close substitutes)—can be explained only in terms of violations of assumptions of the model, for instance interregional variations in factor costs, discontinuous substitutability of factors and non-rational behaviour of planners or entrepreneurs. This paper outlines a less abstract theory in which products may be made by an indefinite number of 'factors' (including specific commodities, imports, raw materials, skills, etc.) whose respective costs increase at different rates as the scale of production is increased.

Discusses the 'local' industry of Kwangtung province which, as elsewhere, is generally less mechanized and smaller in scale than 'central' industry, both concepts being administrative ones. At the time of the first five-year plan (1953–7) there was very little industry, most of it light, and the province was told to concentrate on agriculture and a few light industries. Before the plan there had been a period of rapid expansion of output in the country at large which had led to many problems—irrational distribution of factories, dislocation between materials supply, production and marketing, bad management, high production costs, poor quality, lack of standard specifications, high accident rate, and underutilization of equipment; cadres, enthusiastic for rapid industrialization, overlooked the importance of local industries to agriculture and as adjuncts to larger enterprises.

Despite the existence of such conflicts between output and efficiency objectives, a consistent policy position emerged over the years with regard to local industry in Kwangtung. A complementary relationship grew up between central and local industry, with prior claim to scarce resources given to the former. Local industry was to concentrate on producing

'those industrial goods needed locally throughout the country which cannot be supplied by the central state-owned industry and existing industry'. It could mobilize local raw materials, overcome transportation difficulties and help to satisfy consumer demand.

By 1961 local industry was violating the complementarity principle on a massive scale and hence the Great Leap Forward was brought to an abrupt end—'use steel only for the cutting edge of a knife.' However, local industry has remained important in a number of areas. A significant proportion of fertilizer output is produced in the more than 300 small and medium fertilizer plants in the country as a whole. In Kwangtung there are several thousand native sugar-processing shops and in 1965 they chose to establish seven new medium-scale plants with a daily pressing capacity of only 500 tons of cane.

SIGURDSON, J.: 'The Suitability of Technology in Contemporary China', in *Impact of Science on Society*, vol. xxiii, no. 4 (October–December 1973), UNESCO.

Discusses rural industrial technology in China. Estimates that it provides employment for 2·5 per cent of labour force in Hopei. Describes small-scale hydro-electric power stations (providing estimated 16 per cent of China's hydro-electric power); simple methods to produce marsh gas; manufacture of synthetic ammonia on a small scale and small cement plants. Describes some design modifications made to suit local conditions —e.g. use of bamboo or wood instead of iron in hydro-electric generators, and use of low-quality coal for production of ammonia.

SIGURDSON, J.: 'Technology and Employment in China', *World Development*, vol. 2, no. 3, March 1974.

Describes Chinese manpower and technology policies since 1956, with emphasis on 'walking on two legs' with advanced technology in the modern industrial sector, and small-scale technology for the rural sector suitable for 'economically and industrially primitive conditions'. Since the proliferation of small-scale technologies in 1969–71, emphasis now seems to be shifting towards technical innovations which will raise labour productivity in this sector; additional labour absorption will take place mainly within agriculture.

Describes some rural manufacturing technologies. In the manufacture of cement three different techniques are used for the sintering process: big plants with conventional rotary kilns, small and medium plants using vertical kilns, and very small plants using pitches in the ground. Almost half of output comes from the second and third categories. Production costs in very small plants studied were almost 150 yen per ton (1958) but had fallen to 36 yen in 1970, as plant size increased and the techniques were fully mastered, which compares with costs of 31 yen per ton for a plant of 100,000 tons capacity. The small-scale methods are justified in terms of gradual mastery of techniques and training of workers, quarrying of materials, avoidance of excess capacity, and high transportation costs. Investment can be considerably reduced with a local industrial base which enables the use of makeshift equipment and local adaptations.

Describes the interaction between local industry and agriculture in a county industrial system. Emphasizes the importance of local individual engineering enterprises as the focal point for upgrading skills and technology; 96 per cent of counties have enterprises making machinery. Ball-bearing production is described as an example.

UNITED NATIONS INDUSTRIAL DEVELOPMENT ORGANIZATION: 'Organization and Operation of Cottage and Small Industries in Japan', *Industrialization and Productivity*, Bulletin no. 2 (1959), pp. 37–41.

Discusses the impact of the infrastructural and institutional environment on small Japanese enterprises.

One striking feature of the small enterprise is the use of a single-purpose machine for each specific operation. This saves times in changing tools, dies, and fixtures and ensures better and more output. Such machines can often be cheaper to install and are easy to handle and repair and maintain locally; their total power consumption is much lower. They are often specially designed and manufactured in the factories themselves. Likewise, most small factories have their own draughting and designing sections, development departments, and testing laboratories. Considerable attention is given to the layout of plant and equipment.

UNITED NATIONS INDUSTRIAL DEVELOPMENT ORGANIZATION: 'The Dual Nature of Industrial Development in Japan', *Industrialization and Productivity*, Bulletin no. 8 (1964), pp. 41–52.

Examines the co-existence of the capital-intensive large-scale industries alongside a highly developed small-scale sector using labour-intensive processes and employing a large proportion of the work force for very low wages. This dual development was accompanied by the use of labour-saving techniques, many of them 'borrowed'. The structure of relative prices and absence of labour unions kept wages low for a long time, while the social–economic viability of agricultural and service industries enabled these industries to support the labour force.

The major acceleration in development in the period 1910–36 was strongly encouraged by the government, which provided finance for iron and steel, shipbuilding, and transportation equipment. At the same time the government implemented a variety of policies to improve productivity in small establishments. These included selection of products and processes specifically relevant to small firms, exploitation of economies of scale in, for example, irrigation projects and fertilizers and transfer into small firms of the part of capital assets which was considered to be inefficient in large firms.

In the 1950s the growth rate jumped to 10 per cent p.a. This was accompanied by a sharp increase in the contribution of neutral technological changes and an increase in the share of heavy industry. Inter-firm wage differentials began to increase, and these were related to size since unions are almost all organized by firms, since in large firms employment usually involves a lifetime commitment, and since there was no legal guarantee of minimum wage rates.

WATANABE, S.: 'Entrepreneurship in Japanese Manufacturing', *International Labour Review*, vol. 102 (July–December 1970), pp. 531–76.

Contains a lot of interesting information, much of it sociological. Of particular interest are the following two tables showing the low capital requirements (roughly 700 yen = £1) for entry into manufacturing, and the widespread use of second-hand machinery.

Initial capital requirement for entry into manufacturing ('000 yen)	Fukuoka Report Jan. 1961–Mar. 1967 %	Fujikawa Report Aug. 1964–June 1965 %	KKK Report Jan. 1967–Dec. 1968 %
0–500	48·5	31·8	21·4
500–1,000	24·2	24·2	19·6
1,000–2,000	19·7	34·9	26·8
2,000 and over	7·6	9·1	32·2

Percentage of used machines in the total of machines purchased

	1957		1962	
	4+ workers	4–19 workers	4+ workers	4–19 workers
Lathe:				
Automobiles and components	82·6	90·3	18·5	39·1
Machine and equipment manufacturing	83·6	98·3	25·0	21·9
Bearings	51·7	91·9	25·0	39·9
Sewing machines	68·7	80·4	23·0	25·9
Bicycles and parts	69·8	75·8	20·0	—
Milling machine:				
Machine and equipment manufacturing	90·7	94·1	12·5	21·8
Sewing machines	78·6	100·0	23·0	14·6
Press:				
Automobiles and components	24·7	40·0	19·9	21·2
Bicycles and parts	33·3	33·3	20·1	44·9

SECTION 6

Studies of appropriate technological innovation

AURORA, G. S., and MOREHOUSE, W.: 'Dilemma of Technological Choice: The Case of the Small Tractor', *Economic and Political Weekly*, vol. 7, nos. 31–3 (Special Number, August 1972), pp. 1633–44.

Traces the difficulties which the Indian Central Mechanical Engineering Research Institute encountered in designing and developing the 20-horse-power 'Swaraj' tractor in the face of competition from the Czech 'Zeteor' tractor which would have been a turn-key job. The public sector firm Hindustan Machine Tools opted for the Zeteor on grounds of immediate benefits, but the Punjab State Industrial Development Corporation took up the Swaraj project, seeing the development potential of the project for the area as off-setting its cost, time, and initial quality disadvantages.

The authors discuss the influence of the economic and social climate within India on attempts to develop indigenous technologies which they say are necessary if 'technological colonialism' is to be overcome. Among government policies which constrain such development the authors consider anti-monopoly legislation, industrial relations policy, and the goals which public-sector enterprises are expected to achieve, notably profitability. They emphasize the need for strong policies to overcome such constraints.

BOURKE, W. O.: 'Basic Vehicle for South-East Asia', in *Technology and Economics in Economic Development*, U.S.A.I.D., May 1972.

Report by the president of Ford-Asia-Pacific Inc. of the development of an intermediate vehicle, the 'Fiera', 'more efficient than the traditional animal- or human-powered vehicles but less expensive than the imported vehicles designed for use in developed country markets'. Production technology was designed to be simple enough to be done with 'a 70 ton brake press, a manually operated screw-press, and simple jigs and fixtures which can be welded together out of readily available materials'. The vehicle consists of a simple cab and chassis. Model variations are possible so that it can be used as a truck, a passenger minibus, a van; it can be used to drive a rice-husking machine, power a water pump or a saw. Manufacture is planned in the Philippines in 1973. Total research investment was U.S. $700,000.

GERMAN FOUNDATION FOR DEVELOPING COUNTRIES: *Development and Dissemination of Appropriate Technologies in Rural Areas*, report of a workshop held in July 1972 in Kumasi, Ghana; Seminar Centre for Economic and Social Development, Berlin and University of Science and Technology, Kumasi.

R. Paillon: '*Development of the Tek-Block Press*', pp. 57–66.

Outlines the improvements made to the Latin American Amra Ram hand machine for making cement-stabilized soil building blocks and the organizational arrangements (such as training, incentive schemes, etc.) made to encourage its adoption. Estimates the economics of the process—'at least three houses must be built using the machine to make it economically justifiable; the use of the machine becomes economically interesting at perhaps six houses.'

J. Beck: '*Low-Cost Housing Research for Ghana—Design, Materials, Construction Techniques*', pp. 67–78.

Discusses the improvements to traditional housing which are being fostered by the university.

Also, a number of other articles of a more general nature.

GIRAL, J. B., and MORGAN, R. P.: *Appropriate Technology for Chemical Industries in Developing Economies*, report of a summer research training project held at National Autonomous University of Mexico, July–August 1972, bibliography.

The authors document Mexican cases of successful adaptation of technology for use in small-scale plants supplying a smaller market than would be the case in an advanced country. Such successful adaptation experience, they warn, is not widespread, and its impact is more illuminatingly characterized as capital-saving since the sector as a whole does not lend itself to heavy labour utilization.

The case studies briefly described, cover: updating an obsolete process; change in the reaction conditions in the manufacture of an organic intermediate; expansion of an existing operation through process optimization; extrusion of an optical-quality plastic film; manufacture of a prilled product; straight manufacture of ammonium sulphate; synthetic hormones; paper from sugarcane waste; and steel by direct gas reduction. 'Among the key elements seem to be the use, for smaller markets, of somewhat more labour-intensive materials handling steps and quality control practices, saving upon expensive equipment and utilizing locally available raw materials.'

The rest of the study is taken up with considering ways in which appropriate technologies can be fostered.

RUINA, J. P.: 'Technology Adaption Projects of the M.I.T.', paper presented to study group on the Choice and Adaption of Technology in Developing Countries, O.E.C.D., 1972.

Discusses the projects currently being carried out at MIT. These are into road and air transport, water resources, housing, systems analysis, materials adaption, organizational studies, and R and D.

SANSON, R. L.: 'The Motor Pump: A Case Study of Innovation and Development', *Oxford Economic Papers*, March 1969, pp. 109–21.

Investigates the invention of a motor pump for irrigation which contributed greatly to the development of a major portion of the upper

delta region of the Mekong Delta of South Vietnam in the mid 1960s, and its rapid diffusion to farm users in the absence of a formal communications system or marked government support. The pump proved to be extremely profitable, replaced the water-wheel, and far from displacing labour allowed additional land to be double cropped, raising the ratios of labour to land and capital to land and eliminating widespread seasonal unemployment.

The author makes a distinction between four types of intermediate technology: in the *economic* sense where the best technology is too expensive to warrant its adoption; in the *distributive* sense when the best technology is simply not available, for whatever reason; in the *technical* sense when in the developed economies there is no task similar to that faced in the underdeveloped economy; and finally when a *foreign exchange* bottleneck dictates the use of an intermediate technology.

SECTION 7

Miscellaneous

BHALLA, A. S.: 'Galenson–Leibenstein Criterion of Growth Reconsidered: Some Implicit Assumptions', *Economia Internazionale*, 1964, pp. 241–9.

The Galenson–Leibenstein thesis relies on the explicit assumptions that all profits are reinvested and that all wages are consumed. This article examines the further implicit assumption of a uniform wage rate, with reference to the Indian cotton textile industry. Taking numbers employed as a criterion of plant size the author argues that the plants with the highest I/L ratio are of medium size (250–499), that the wage rate is positively correlated with the size of plant, that surplus per person is higher in the 100–249 size group than in the 250–499 size group, and that even when capital-intensive techniques yield a larger surplus per person, the total surplus generated may be smaller.

DIAZ-ALEJANDRO, C. F.: 'Industrialisation and Labour Productivity', *Review of Economics and Statistics*, May 1965, pp. 207–14.

Examines the empirical basis of Hirschman's hypothesis that capital-intensive, machine-paced industries help to economize on scarce managerial resources, namely, that labour productivity differentials between LDCs and developed countries should be much larger in labour-intensive than in capital-intensive industries. Presents data for a number of industries in the U.S.A. and in Argentina on labour productivity, and three measures of labour-intensity, viz.: the ratio of the wage bill to value added, physical plant size, and number of production workers. The data suggest that Hirschman's hypothesis may apply to quite a range of industries, though there are also a number of strong counter-examples. Several industries achieved high productivity where quite low productivity would have been forecast on Hirschman's hypothesis, suggesting that shortage of managerial talent may not be an overriding constraint.

HEALY, J. M.: 'Industrialisation, Capital Intensity and Efficiency', *Bulletin of the Oxford University Institute of Economics and Statistics*, November 1968, pp. 323–40.

Investigates the empirical basis of Hirschman's hypothesis, namely, that the greater the capital-intensity of each industry the smaller will be its labour productivity differential between countries at different levels of development, with reference to 110 industries in India and the U.K. Productivity is measured in terms of value added per operative and no adjustments are made for variations in capacity utilization; capital-intensity is measured as book value of fixed capital per operative.

The data suggest no clear support for or refutation of the hypothesis. However, 'in considering the extreme results, the hypothesis that very labour-intensive industries are particularly inefficient receives more support than the hypothesis that very capital-intensive industries are especially efficient in an industrially immature country.'

In a number of cases industries producing similar products have widely differing capital-intensities. Regression analysis suggests that capital-intensity, but not plant size or the degree of mechanization (electric power per operative), is strongly associated with relative labour productivity.

See also entries for C. F. Diaz-Alejandro (1965) and J. Gouverneur.

HIRSCHMAN, A. O.: *The Strategy of Economic Development*, Yale University Press, 1958.

Chapter 8 puts forward the hypothesis that in many cases capital-intensive industries contribute most to the economic development of developing countries on the ground that machine-paced processes are a substitute for managerial skills.

HONE, A.: 'The Employment Potential of Appropriate Technologies and Export-Based Industrialisation in South Asia: Analysis and Policies', mimeo, Institute of Commonwealth Studies, Oxford, 1974.

HUGHES, K.: 'Factor Prices, Capital Intensity, and Technological Adaptation', in *Contemporary Brazil: Issues in Economic and Political Development*, ed. H. J. Rosenbaum and W. G. Tyler, Praeger, 1972, chapter 6, pp. 125–38.

Discusses the causes of the excessive capital-intensity of Brazilian industry since 1950. On the basis of interviews with some forty Brazilian manufacturing firms the author gained the impression that in general the range of productive technique from the point of view of the profit-maximizing entrepreneur was small, and that the use of shadow prices of capital and labour would make little difference. Even ancillary functions may not long be exempt from mechanization. For a variety of reasons the situation was little different in the north-east from that in the centre-south, among them being the lack of industrial skills and the prevalence of malnutrition and disease.

HUSAIN, A. F. A.: *Human and Social Impact of Technological Change in Pakistan*, Oxford University Press, Pakistan, 1956.

Describes technological changes in East Pakistan, based on field survey of nineteen factories and rickshaw workers. Describes human and social impact of technological change—e.g. new factories associated with higher incomes for workers than previous occupations, but worse housing, worse diet, poor health, high absenteeism, and considerable maladjustment.

INTERNATIONAL LABOUR OFFICE: *Towards Full Employment: A Programme for Colombia*, I.L.O., Geneva, 1970.

Chapter 11 discusses the possibilities of using more labour-intensive techniques.

MARSDEN, K.: 'Progressive Technologies for Developing Countries', *International Labour Review*, vol. 101 (January–June 1970), pp. 475–502.

A general survey of the arguments for appropriate technologies in LDCs, containing many illustrations.

MERHAV, M.: *Technological Dependence, Monopoly and Growth*, Pergamon Press, Oxford, 1969.

A largely theoretical analysis of the problems developing countries face from the monopolistic market structures brought about by the import of Western technologies. Appendix IB contains capital cost–capacity and labour cost–capacity ratios calculated from U.S., Japanese, Soviet, and Latin American data for the following industries: ammonium nitrate, beer bottles, radial ball-bearings, taper roller-bearings, tar, benzole, cement, finished steel, aluminium plant, and food canning.

PFEFFERMANN, G.: *Industrial Labour in the Republic of Senegal*, Praeger, New York, 1968, pp. 172–97.

Chapter 11 discusses choice of techniques in former French tropical territories. The author emphasizes that influence over choice of industries is easier than influence over the choice of techniques within industry.

A number of factors encourage the use of capital-intensive techniques. The low productivity of unskilled African labour leads both to substitution of machines for labour, and also to the use of machines to increase labour productivity—many expatriate employers interviewed considered large investments in technically advanced capital goods to be a prerequisite to an economic use of cheap labour. Capital goods tend to be standardized to produce for the markets of advanced economies, and the requirements of the expatriate labour market tend to reinforce standardization. Monopoly position and tariff protection increase the ability of firms to depart from socially optimal factor allocation.

Most industrialists interviewed stated that there was no choice of technique open to them since the choice of capital equipment is determined by the markets of the advanced countries. Some said that although there were choices for each process within their firm considered separately, once a choice was made for one process this by and large determined the choices for each of the other processes. Ancillary operations are generally an exception.

The manager of the Senegalese match factory justified increased mechanization on the grounds that: '(*a*) the quality of the product had improved greatly, making it capable of facing international competition; (*b*) problems of personnel management and supervision had been greatly alleviated and labour relations had improved; (*c*) the rate of absenteeism fell; (*d*) piece-work could be replaced by hourly wages representing a better remuneration for most workers; (*e*) the need for expatriate

supervision was reduced, enabling the firm to raise the quality of the expatriate labour force, thereby making it less likely to be attacked by the government on political grounds for Africanization; (*f*) the new plant is very similar to a recently built sister-plant in the Ivory Coast, thus reducing over-all costs for the international firm.'

Indigenous firms are far more capital-saving than the expatriate ones, but seldom expand so as to be able to compete. The author argues that this is the result of discrimination in both capital and labour markets which bars them from obtaining competent management and cheap capital.

RANIS, G.: 'Investment Criteria, Productivity and Economic Development: An Empirical Comment', *Quarterly Journal of Economics*, May 1962, pp. 298–302.

Argues that the total ploughback of profits in relation to capital stock in the textiles, light engineering, plastics and leather, and leather goods industries in Karachi is maximized in medium-scale plants, thus throwing doubt on the Galenson–Leibenstein hypothesis. The criterion of capital-intensity used is size of plant in terms of numbers employed.

RANIS, G.: 'Some Observations on the Economic Framework for Optimum LDC Utilization of Technology', in *Technology and Economics in International Development*, U.S.A.I.D., Washington D.C., May 1972.

Discusses the mechanisms of technology transfer, with empirical evidence from Korea, Taiwan, and Japan.

RANIS, G.: 'Industrial Sector Labor Absorption', in *Economic Development and Cultural Change*, vol. 21, no. 3 (April 1973), pp. 387–408.

Provides a historical and policy perspective for the generally poor record of industrial labour absorption and argues that 'labour surplus developing countries, well within their efficiency frontier, may be able . . . to enjoy more employment, more growth, and more income distribution at the same time.' This arises from their 'indigenous capital-stretching capacity', that is, their capacity to reach higher levels of labour productivity accompanied by lower I/O ratios.

In post-Restoration Japan capital-stretching innovations took the form of running imported machinery at rates and speeds substantially higher than those used abroad and of saving plant through exploiting complementarities between many small labour-intensive units and the large industrial-management unit (the subcontracting system). As evidence that such innovations were in response to differences in factor endowments the author cites the continued use of non-automatic looms until indigenous entrepreneurial and skilled labour capacities were adequate, whereas the latest automatic spinning equipment was used much sooner.

A similar pattern of capital-stretching is apparent in Korea since the devaluation of 1964 and the interest rate reform of 1965, and in Taiwan since the liberalization policies of the early 1960s. Perhaps the most interesting development has been the extension of subcontracting to the international level.

SACHS, I.: 'Selection of Techniques: Problems and Policies for Latin America', in the *Economic Bulletin for Latin America*, vol. 15, no. 1, first half of 1970.

A theoretical discussion which includes a critique of the factors biasing the Latin American economies (inappropriately) towards choice of capital-intensive technologies. These factors include subsidized credit and fiscal rebates which are wastefully spent on over-capitalized equipment, and the high rate of inflation which encourages expenditure on prestige construction, while there is often an acute shortage of working capital. At the same time various labour taxes and fringe benefits increase the price of labour, while the tense labour situation often makes it unattractive to choose labour in preference to capital.

SCHUMACHER, E. F.: 'Industrialisation through Intermediate Technology', in R. Robinson (ed.): *Industrialisation in Developing Countries*, Cambridge University Overseas Studies Committee Conference on Role of Industrialization in Development, Cambridge, 1965.

Argues the case for intermediate technology.

SEN, A. K.: 'Working Capital in the Indian Economy: A Conceptual Framework and some Estimates', in P. N. Rosenstein-Rodan, *Pricing and Fiscal Policies*, George Allen & Unwin, 1964, chapter 6, pp. 125–47.

Discusses perhaps the most neglected aspect of capital formation, working capital, and one which is crucial to any attempt to measure the capital-intensity of an industry.

The working capital requirement consists of: (*a*) work-in-progress, which is a function of the cost of recurring inputs per unit of output flow and the time lags between the application of recurring inputs and the arrival of outputs; (*b*) the stock of finished goods, which will comprise a transaction hoard, and a speculative hoard, and in a few cases a precautionary hoard too; and (*c*) the stock of raw materials, which will again consist of a transaction, a speculative, and perhaps a precautionary part.

A special problem is posed by the value of labour in the pipeline since from the national viewpoint one must consider the alternative use of labour and the additional consumption generated by additional employment. Here it is important to distinguish between inventory *qua* stock of goods and inventory in the sense of capital necessary to induce the application of incremental labour. It is the latter which we are interested in and in a non-wage (i.e. rural household) economy this stock need not be increased prior to expanding production; rather the expansion of this stock, which is a *consumption* stock, is only a *result* of increased output. This has important planning implications where there is the possibility of converting household-based economies into wage-based ones.

From an examination of data from various sources on different sectors of the Indian economy the author arrives at the following estimates of

the ratio of working capital to *net value added* during the period of the third Five Year Plan (1960–5):

Manufactures	1·05	Reliable
Mining	0·24	Not very reliable
Small enterprises	0·50	Shaky
Trading	1·10	Not very reliable
Agriculture	0·14	Quite reliable
Construction and railway	0	Convention
Over-all	0·40	

This contrasts with an over-all allowance for working capital of 16 per cent of total net investment in the Third Plan, a considerable shortfall. This implies that saving and investment in India have been considerably higher than has generally been recognized.

STRASSMAN, W. P.: *Technological Change and Economic Development: The Manufacturing Experience of Mexico and Puerto Rico*, Ithaca, 1968, chapters 4 and 5, pp. 112–94.

The author conducted interviews during the period 1960–3 to determine the factors affecting investment decisions in seventy firms. He discovered that factors encouraging capital-intensity were: low interest rates, ranging from 5–20 per cent in a time of 7 per cent inflation; tax incentives to reinvest profits; various market imperfections encouraging substitution of capital where organizational skills are in short supply, namely, wide variations in wage rates, training costs, productivity, absenteeism, turnover, etc.; in the case of Mexico, high redundancy payments stipulated by law; and high wages inasmuch as they discourage capital from entering and labour from leaving.

Two-thirds of the firms in Mexico said they would not have bought more equipment if they had been able to borrow more. Just over 30 per cent of these firms said that the choice of technique was affected by interest rates.

Only one interviewee thought that he could have reduced costs by using less mechanization and more labour, whereas 29 per cent thought they could profitably install extra equipment to facilitate the current volume of production. Sixty-two per cent of firms contemplating higher capital-intensity in existing product lines thought that this would lead to higher output; some wanted improvements in quality.

It is argued that an important factor determining mechanization in auxiliary processes was the scale of output involved: one large bakery had a conveyor belt for the continuous cooling of bread, whereas a smaller one used stationary hand-loaded cooling racks. In 53 per cent of Puerto Rican and 70 per cent of Mexican plants, auxiliary processes were modified in comparison with U.S. practice.

Ten per cent of the Mexican and Puerto Rican firms used multi-purpose equipment which would be unusual in an equivalent U.S. plant, while another 40 per cent used standard equipment for more than one phase of production, often at the expense of continuous-flow layouts. Large firms were found to be more adaptive than small, one reason being that workers could more easily be shifted from one operation to another.

Discusses intensive staffing and multiple-shift working as means of

increasing labour-intensity. In 1956 the shift coefficient for Mexican manufacturing was 1·07, compared with 1·14 in New York and 1·45 in Detroit; among the highest in Mexico were basic metals (1·55), petroleum (1·46), and paper (1·22). Out of a sample of 70 'new and progressive' firms, 29 operated two or more shifts in all departments, and a further 9 in a few departments; size and multishift working were positively correlated. Of the 38 firms operating multiple shifts, 31 did so for compelling technical reasons, such as not stopping furnaces.

Discusses the possibility of local machinery production, and the role of maintenance, durability, and second-hand equipment.

TYLER, W.: 'Employment Generation and Promotion of Manufactured Exports in Less Developed Countries: Some Suggestive Evidence', mimeo, Kiel, 1973.

WEISSKOFF, R., LEVY, R., NISONOFF, L., and WOLFF, E.: 'A Multi-Sector Simulation Model of Employment, Growth and Income Distribution in Puerto Rico: A Re-evaluation of "Successful" Development Strategy', mimeo, Yale Economic Growth Center, 1973.

Finds that a ten-year 'technology freeze' policy in Puerto Rico could have increased 1963 employment by 400,000 jobs or 40 per cent: 150,000 jobs 'lost' were due to inter-industry flows, 1953–63; the rest to increases in productivity.

YEOMAN, W. A: 'Selection of Production Processes for the Manufacturing Subsidiaries of US Based Multinational Corporations', unpublished DBA thesis, Harvard Business School (April 1968).

Argues that the U.S. firm is more likely to depart from its U.S. technology in low-wage countries if the basis of competition is primarily price. Also suggests that U.S. firms adjust their technology more, in low-wage countries, for light manufacturing than for heavy manufacturing. This greater adjustment for light manufacturing probably reflects the existence of a wider range of known, feasible technologies for light industries.

SECTION 8

Addendum

BHALLA, A. S. (ed.): *Choice of Techniques and the Employment Problem in Manufacturing*, Technology and Employment series of the International Labour Organisation World Employment Programme, Geneva, forthcoming.

Contains chapters on issues of concept and measurement by A. S. Bhalla, J. Gaude, and J. Krishnamurty. The empirical case studies cover: the copper and aluminium industries, by P. Della Valle; can production in Kenya, Tanzania, and Thailand by Charles Cooper and Raphael Kaplinsky (q.v. I.L.O. Kenya Report entry for findings on Kenya); second-hand machines in jute processing in Kenya, by Charles Cooper and Raphael Kaplinsky; the textile industry, by Howard Pack; sugar processing in India, by C. G. Baron; cement blocks in Kenya, by Frances Stewart (q.v. p. 36), the engineering industry in Colombia, by Norton Young, German Valenzuela and Peter Montes; metal-working in Mexico, by G. K. Boon (q.v. p. 20).

ENOS, J. L.: 'More (or Less) on the Choice of Technique, with a Contemporary Example', mimeo, Magdalen College, Oxford, April 1974.

Discusses the production of salt in S. E. Asia. See also the entry for Asian Industrial Survey for Regional Co-operation, pages 17-18 above.

INTERNATIONAL LABOUR OFFICE: *Employment, Incomes and Inequality: A Strategy for Increasing Productive Employment in Kenya*, Geneva, 1972.

Contains studies of choice of technique in can manufacture (pp. 371-82) (q.v. Bhalla above) and in road construction (pp. 383-90).

INTERNATIONAL LABOUR OFFICE: World Employment Programme Working Papers:

BARON, C. G.: 'Sugar Processing Techniques in India', preliminary mimeo report, January 1973 (q.v. Bhalla above).

BHALLA, A. S.: 'Concept and Measurement of Labour-Intensity', WEP 2-22, August 1974 (q.v. Bhalla above).

COOPER, C., KAPLINSKY, R., and TURNER, R.: 'Second-Hand Equipment in a Developing Country: A Study of Jute Processing in Kenya', WEP 2-22, Geneva, November 1973 (q.v. Bhalla above).

ERIKSSON, R., YLLO, A., and LUNDGREN, N.: 'Thai Workers in Heavy Road Construction Activities—An Ergonomic Pilot Study', WEP 2-16, Geneva, April 1974.

GAUDE, J.: 'Capital–Labour Substitution Possibilities: A Review of Empirical Research', WEP 2-22, Geneva, May 1974 (q.v. Bhalla above).

KRISHNAMURTY, J.: 'Indirect Employment Effects of Investment in Industry', WEP 2-22, Geneva, July 1974 (q.v. Bhalla above).

LAL, D.: 'Men or Machines: A Philippines Case Study of Labour–Capital Substitution in Road Construction', WEP 2-22, Geneva, October 1973 (q.v. entry for I.L.O.: 'Roads and Redistribution' on page 28).

PACK, H.: 'The Choice of Technique and Employment in the Textile Industry', WEP 2-22, Geneva, March 1974 (q.v. Bhalla above).

SMITH, L. D., and BROWN, C. J. F.: 'Employment and Coffee Production Techniques: An International Comparison', WEP 2-22, Geneva, February 1974.

SHARPSTON, M. J.: 'Capital–Labour Substitution Possibilities: An Empirical Approach', mimeo, IBRD, Washington, July 1973.

Discusses 'at a factory-floor level what capital/labour substitution typically involves'. Deals principally with the metal-working industry.

SECTION 9

Other relevant bibliographies

BARANSON, J.: *Technology for Underdeveloped Areas: An Annotated Bibliography*, Pergamon Press, 1967.

INTERMEDIATE TECHNOLOGY DEVELOPMENT GROUP: 'Bibliography of "Intermediate" or "Appropriate" Technology', mimeo, ITDG, Parnell House, 25 Wilton Road, London, S.W.1, 1973.

INTERMEDIATE TECHNOLOGY DEVELOPMENT GROUP: 'Bibliography on Low-Cost Water Technologies', ITDG, London, 1971.

INTERMEDIATE TECHNOLOGY DEVELOPMENT GROUP: a forthcoming list of available appropriate technologies.

INTERMEDIATE TECHNOLOGY DEVELOPMENT GROUP: *Tools for Progress—1967–1968: Guide to Equipment and Materials for Small-Scale Development*, London, Unwin Ltd., 1967.

JACKSON, S.: *Economically Appropriate Technologies for Developing Countries: A Survey*, Overseas Development Council, Suite 501, 1717 Massachusetts Avenue N.W., Washington D.C. 20036.

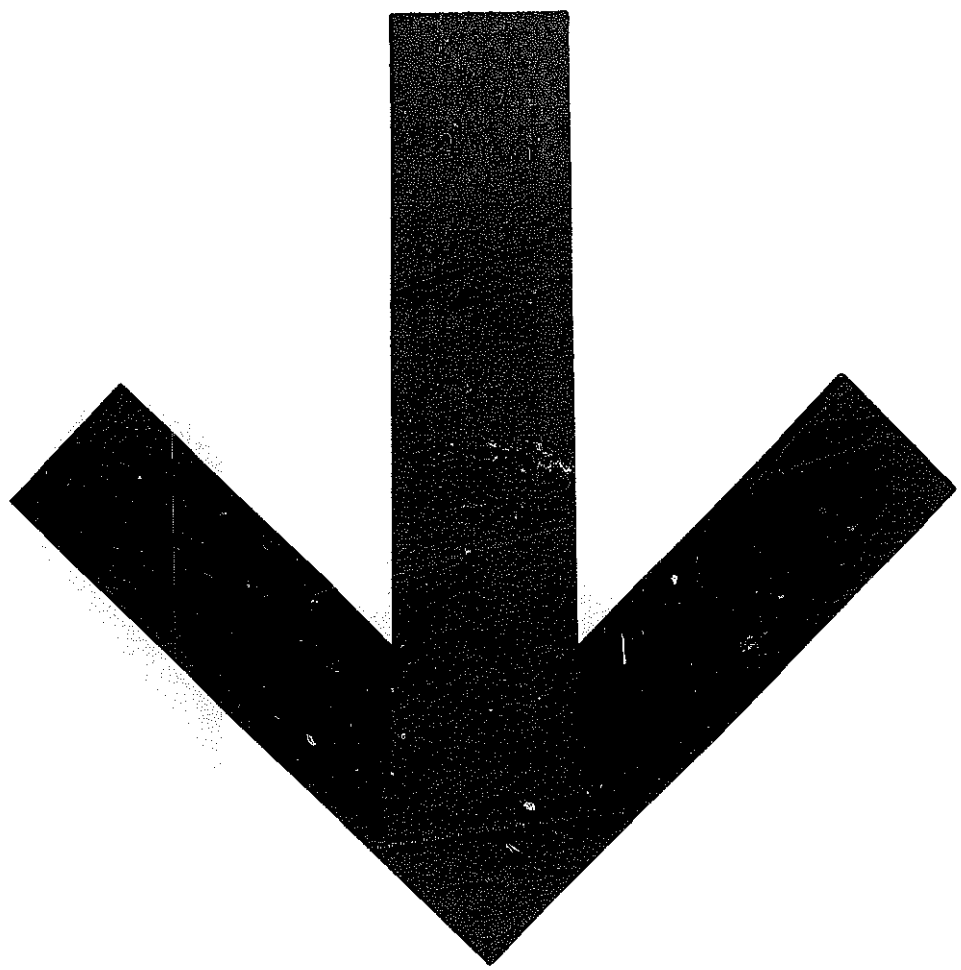
ORGANISATION FOR ECONOMIC CO-OPERATION AND DEVELOPMENT: *Transfer of Technology and Appropriate Techniques: A Bibliography*, OECD Development Centre, 94 rue Chardon-Lagache, Paris–16e.

SMALL INDUSTRY EXTENSION TRAINING INSTITUTE: *Appropriate Technology: Documentation Bulletin*, SIET Institute, Hyderabad 500045, in conjunction with the Appropriate Technology Cell, Ministry of Industrial Development, Udyog Bhavan, New Delhi 110011, quarterly from 1973.

SMALL INDUSTRY EXTENSION TRAINING INSTITUTE: *Sendoc Bulletin: Bulletin of the Small Enterprises National Documentation Centre*, SIET Institute, bi-monthly from 1973.

TROPICAL PRODUCTS INSTITUTE: *Publications List*, TPI, 56–62 Gray's Inn Road, London, W.C.1, November 1971.

VAIKUNTHBAI MEHTA SMARAK TRUST: *Documentation Bulletin for Small Scale Industries*, NKM International House, 178 Backbay Reclamation, Mme Cama Road, Bombay, quarterly from 1970.



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